MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

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VOLUME XXXIX

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PART I.

THE GEOLOGY OF NORTHERN AFGHANISTAN: BY H. H. HAYDEN, DIRECTOR, GEOLOGICAL SURVEY OF INDIA. (With 20 plates).

PART 2.

GEOLOGY OF THE NORTHERN SHAN STATES: BY T. H. D. LA TOUCHE, M.A., F.G.S., LATE OFFICIATING DIRECTOR, GEOLOGICAL SURVEY OF INDIA. (With 27 plates and 11 Text Figures.)

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THE GEOLOGICAL SURVEY OF INDIA.

THE GEOLOGY OF NORTHERN AFGHANISTAN: BY H. H. HAYDEN, *Director, Geological Survey of India.*

I.—INTRODUCTORY.

Nearly a quarter of a century ago, Mr. C. L. Griesbach spoke of Afghanistan (**11**,[1] 94) as being "geologically still a *terra incognita*"; this description holds good almost equally at the present day. What little we know of Afghan geology is due chiefly to Mr. Griesbach's own work in that country between the years 1880 and 1888, the scientific results of which were published in the *Records of the Geological Survey of India*, Vols. XVIII, XIX, XX, and XXV. Since then nothing has been published on the subject, and the small amount of purely scientific work that I was able to do, during a short tour undertaken primarily for the investigation of economic questions, has tended to confirm, on the whole, and to some extent to amplify Mr. Griesbach's conclusions.

[1] The numerals printed in heavy type refer to the papers included in the bibliography on pp. 28 to 84. The other numerals refer to the page of the work quoted.

B

The conditions under which my tour was made were peculiarly unfavourable to systematic scientific work, and the prevailing ignorance of the geological conditions of Afghanistan must be my excuse for publishing the following notes based on hasty and disconnected observations. The area traversed lies to the north and west of Kabul, and includes the districts of Ghorband, Bámián, Saighán, and Káhmard. The route followed lay from Kabul, *viá* Koh-i-Dáman to Ghorband, thence across the Shibar pass and Kotal-i-Kashka to Bámián, through Saighán and Káhmard, to the Kotal-i-Saozak (Sabz kotal). On either side of this line, my reconnaissances extended as far as Barfak on the east, and Khárgin dara[1] (Western Saighán) on the west. The return journey was made along the same route, except that, instead of returning *viá* Ghorband, I marched in from Bámián *viá* Kálu, Gardan Diwál on the Helmand, the valley of the Kabul river, and Arghandi.

Throughout this area, the strike of the rocks is in the main S.W.-N.E., and the dip northerly; consequently, from Kabul outwards one crosses an ascending series of which the oldest member is found in the Paghmán range and in the hills around Kabul. The beds are almost always greatly disturbed, and their relations often complicated by intrusive igneous rocks, both basic and acid. The prevailing tectonic element is the reversed fold, the crest of which, as in the Himalaya, leans over to the south; the trend of the folds is, in the eastern parts of the area, N.E.-S.W., gradually bending round to E.-W. in Bámián, Western Saighán and Káhmard.

The orographic features are largely influenced by the tectonic, and the trend of the ranges and valleys corresponds closely with that of the folds. This is particularly well-marked to the north of the Hindu Kush, where such valleys as Saighán and Káhmard run for many miles each parallel to a single fold. These valleys now appear to lie in synclinal troughs, but their positions were no doubt originally determined

[1] *Kotal* = pass; *dara* = valley or ravine. I have in most cases employed the terms *dara* and *kotal* instead of their English equivalents, as they are usually essential parts of the place names.

by the weakened, not infrequently broken, middle limb of the recumbent fold. The structure of this particular area is instructive, since it is typical of the tectonic conditions prevailing throughout Northern, and probably much of Western, Afghanistan.

Between Saighán and the Kárá kotal, that is to say, in a meridional distance of some twenty miles, there are three major folds, *viz.*, the Saighán fold, the Dasht-i-Safed fold, and the Bajgáh (Káhmard) fold. I have traced the first of these from Ishpushta across the Kotal-i-Kálich to Kala-i-Wakil above Saraiak; it is a recumbent anticline of the type

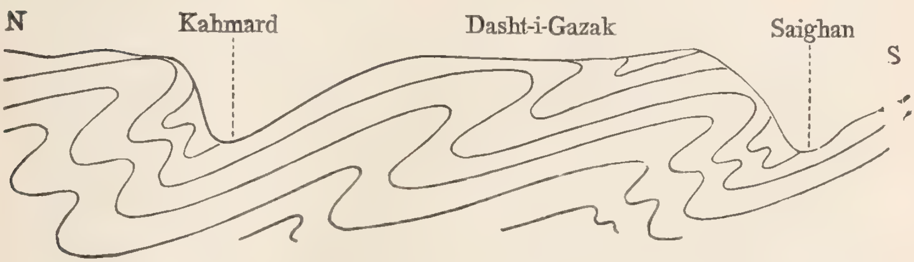


FIG. 1.

Diagrammatic section to show the chief tectonic features in Káhmard and Saighán.

of those shown in figure 1 and is complicated by the occasional presence of a thrust-plane through the middle limb of the second (lower) minor fold. The next flexure is well seen in the hills behind Dasht-i-Safed (Plate 2) and can be traced across the valley and to the north of the Kotal-i-Nálifarsh, whence it runs through the Dasht-i-Gazak and along the northern side of the valley of Sayad Bábá. It is accompanied by a considerable amount of fracture (fig. 2); a thrust-plane can be traced on both sides of the valley at Dasht-i-Safed and is probably continuous into Sayad Bábá and Begal (Plate 3). The Bajgáh fold is beautifully exposed in the gorge between Bajgáh and Mádar; it is of exactly the same type as the others and runs along the northern side of the Káhmard valley and through the hills to the south of Hájar.

To the south of Saighán the conditions become more complicated as we approach the region of the Hindu Kush and Koh-i-Bábá. The same trend and the same type of flexure still prevail in Bámián and Ghorband, but the folds are more numerous and more compressed and faults—in most cases overthrusts—add still further to the complexity. The intrusive granite of the Hindu Kush and Koh-i-Bábá, while obscuring stratigraphical details, tends to define more clearly the tectonic trend-lines; like the Himalayan granite, to which it is in all respects similar, its intrusion, no doubt, took place concurrently with the orogenic movements that gave rise to the mountains in which it occurs, and it forms the cores of the flexures.

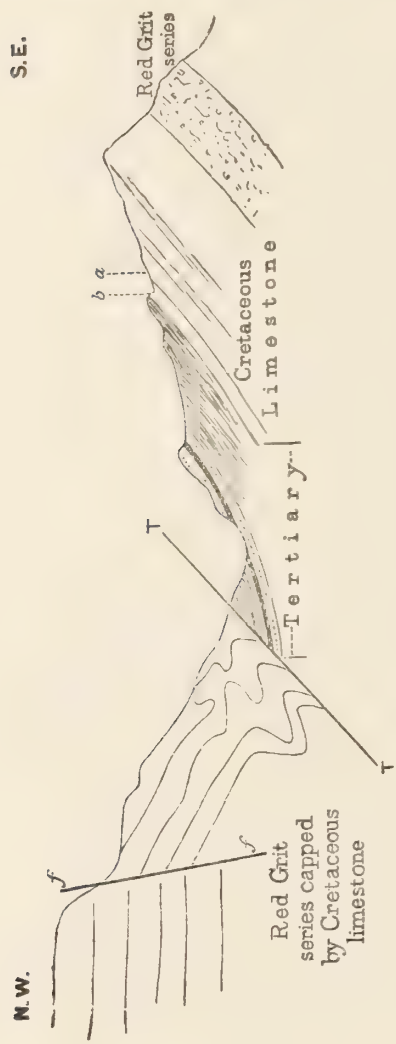


Fig. 2.

Diagrammatic section across valley about 2 miles N.N.E. of Dasht-i-Safed.
f—f, fault; T—T, overthrust.

Both from a geographical, as well as from a geological, point of view, the most important physical features are the Hindu Kush range and the Koh-i-Bábá, along the crests of which runs the line of water-

parting between the basins of the Helmand and Kabul river-systems on the one side and the northward-flowing tributaries of the Oxus on the other. It was probably this feature that led Professor Suess to assume that the Koh-i-Bábá was the direct continuation of the Hindu Kush (**29**, 293). Strictly speaking, however, this assumption is not justified from either a geological or a purely geographical point of view. The crest lines of the two ranges are in no sense continuous; the line of water-parting connecting the two lies on the Shibar pass, which is merely a broad saddle running transversely to the strike of its component rocks. The true easterly continuation of the Koh-i-Bábá is found in the complicated series of ridges to the south of the Ghorband valley, whilst the westerly continuation of the Hindu Kush is the Koh-i-Ghandak and the range between Bámián and Saighán. This view corresponds not only with the actual topographical features but also broadly with the distribution of the stratigraphical series forming the respective ranges.

Although it is not admissible to regard the Koh-i-Bábá as strictly the continuation of the Hindu Kush, both ranges are no doubt parts of a single tectonic system, and have been treated as such by Colonel Burrard (**3**, 100), who offers two alternative interpretations of the orographical relationships of the Afghan water-parting. In one of these he refers the whole mass embracing the Hindu Kush proper,[1] the Paghmán, Sanglákh and Koh-i-Bábá ranges, to two parallel ranges, a northern and a southern Hindu Kush. The northern, which corresponds with the Hindu Kush proper, he regards as the water-parting between the Oxus on the one side and the Indus and Helmand on the other. To the west of Ghorband and the Shibar pass, however, this water-parting is no longer the Hindu Kush proper, but shifts southward to the Koh-i-Bábá, which is shown as the continuation of the so-called Southern Hindu Kush. The other interpretation (*op. cit.*, Chart XXI), offered by Colonel Burrard, is that from Tirich Mir westwards the

[1] *Hindu Kush* is in reality the name of a pass between Ghorband and Khinján, which, according to local folklore, was so named in consequence of the murder (Pers. *kushtan* = to kill) of a Hindu for the sake of his *postin* (sheep-skin coat). Sir Thomas Holdich gives a different, and perhaps more probable, origin for the name [" India ", p. 65 (1904)].

Hindu Kush is a single range, the "Northern Hindu Kush" just mentioned, while the Koh-i-Bábá and other ranges to the south of the Ghorband and Panjshir valleys are the continuation of the Kailas range. It is doubtful if either of these alternatives will entirely meet the case.

Plate 1 is the result of an attempt to determine the chief orographic trend-lines of the Afghan water-parting and neighbouring areas; it has been derived from the North-West Transfrontier sheets (1 inch = 4 miles) of the Survey of India, by reduction by pantograph. It must be remembered that the geology of by far the greater part of this area is unknown and it is impossible to say therefore how far the apparent trend-lines can be regarded as truly orogenic. Where, however, we have geological information, as in the extreme west and again over much of the eastern part of the country, we find that the main topographic features conform with considerable accuracy to the tectonic conditions and it is fair to assume that similar relations prevail in the intervening areas. Working on this assumption we see that between Tirich Mir and Persia the trend-lines follow a curve which is convex towards the south; beginning with a N.E. - S.W. direction they gradually bend through E.-W. to S.E. - N.W., which latter trend would carry them on through the mountains of Persia to meet the system of the Caucasus.

The most striking feature in this diagram is the great trough which extends almost continuously from the Kotal-i-Anjumán at the head of the Panjshir valley, through Ghorband, Bámián and the Hari Rud to Hérát. In the eastern valleys its direction is strictly that of the axes of the neighbouring folds; similar conditions appear to prevail also to the east of Hérát, but what happens in the interval of some 250 miles we do not know. To the west of Hérát the Hari Rud soon bends away to the north and presumably loses its parallelism to the tectonic trend-lines. From Mr. Griesbach's description of the country to the west and north-west of Hérát it would appear that a continuous belt of Upper Palæozoic rocks extends from Khorasan south-eastwards to the Doshákh mountains and thence eastwards to the Davendar range; it is therefore cut through by the Hari Rud to the

Plate I

1. Hindu Kush
2. Koh-i-Ghandak
3. Koh-i-Baba
4. Paghman range
5. Siah Koh
6. Safed Koh
7. Khingil range

SKETCH-MAP OF THE APPARENT TREND-LINES OF AFGHANISTAN. SCALE, 1 INCH = 96 MILES.

(The black lines represent rivers.)

west of Hérát. For the greater part of its course, however, the Panjshir-Hari Rud trough would certainly appear to be a truly tectonic feature. We know too little of it to attempt to dogmatise as to its origin; but one is rather tempted to associate it with an important fault which runs along the northern side of the Koh-i-Bábá and probably extends into Ghorband (*infra*, p. 54). A similar fault was observed by Mr. Griesbach on the northern side of the Dosháḱh mountains near Hérát and is suggestive of a line of structural weakness all along the southern side of the trough. The constant seismic activity of Kabul and Hérát also suggests the existence of important faults analogous to those of the Outer Himalaya.

Whatever be its origin, the Panjshir-Hari Rud trough constitutes a well-marked line of division between the Hindu Kush and the Koh-i-Bábá, and it compels us to look for the true western continuation of the former range in the hills along its northern side between Ak Robát and Hérát and for the eastern continuation of the latter range in the hills of the Ghorband valley and Paghmán. What the relationship of these two ranges to one another is between Panjshir and Tirich Mir, in the hills of Kohistan and Kafiristan,[1] is hardly even worth conjecturing, so limited is our knowledge of the topography, whilst of the stratigraphy we know absolutely nothing.[2] From the great Tirich Mir *massif* westwards we begin to draw away from the stable Indian *vorland* which is replaced by the depression of the Arabian Sea; the folds have room to expand, and the high, closely appressed flexures of the Himalayan arc pass into the lower and more open systems of Afghanistan and Baluchistan. The disposition of the trend-lines of the mountains of Afghanistan is therefore the result of the virgation (**27**, 275) not merely of the Hindu Kush, but of the whole Himalayan system[3] and,

[1] Since the conquest of this country by the late Amir of Afghanistan in 1895 and the conversion of the inhabitants to Islam, it has been re-named Nuristan (from the Arabic word *nur*=light).

[2] The U-shaped bend in the water-parting to the east of Panjshir is evidently not a tectonic feature but merely the work of rain and rivers.

[3] Since the above was written, a very valuable and suggestive paper, by Mr. F. B. Taylor, dealing in part with the peripheral mountain arcs of Asia, has appeared in the Bulletin of the Geological Society of America (Vol. 21, no. 2, June 1910).

until we shall have made stratigraphical as well as topographical surveys of the intervening area, it will be impossible to correlate with certainty the ranges of Afghanistan with those of the Himalayan arc.

The propriety of applying the name Hindu Kush to the various ranges resulting from this virgation was long ago questioned by Mr. Griesbach, who took exception to the inclusion under the name "Hindu Kush" of the Safed Koh and associated ranges on the south-eastern frontier of Afghanistan; he says (**13**, 63): "North and east of Kabul the traveller enters the mountainous country of the great ranges which traverse entire Afghanistan as an unbroken chain, with their subordinate off-shoots on both sides of the watershed. This latter may be said to begin in the highly elevated mountain ranges which bear generally the name of Pamir, of which there are several; we really know too little of the orography of that region to be able to decide in what manner this mountain tract is linked on one side to the North-Western Himalayas, and on the other to the great watershed of Afghanistan. If we follow the latter, it appears that after a very nearly east to west strike near the 37° latitude it assumes a more south-westerly direction till it reaches the mountain centre east of Bámián, within which the three river systems arise, of the Kunduz and Balkh drainage, the Kabul river system, and the Helmand, the latter which drains into the Seistan lakes. Now to this great watershed Eastern, as well as English Geographers have applied the name of Hindu Kush; by it is meant the watershed formed of the great peaks and chains between the Little Pamir and the Shibar pass, east of Bámián, and no other system of ranges, except the spurs closely connected orographically with it on both flanks of it. To extend the name to outlying ranges, which have not even a common direction, *i.e.*, are not even parallel with the line of watershed here described and differ absolutely in their geological structure from that of the Hindu Kush would only tend to hopelessly confuse all geographical expressions. I may here mention that the people of the country itself, living on the slopes of the Hindu Kush, really apply this name only to the pass Kotal-i-Hindu Kush between

the Shibar pass and the Kotal-i-Chahardar,[1] but I found that Afghans, in speaking in general terms of the great range which divides the Kabul province Kafiristan and Chitral from Badakhshan, do make use of the name of Hindu Kush." Although the tectonic system, of which the Hindu Kush is a part, continues throughout Afghanistan and Persia, I fully endorse Mr. Griesbach's opinion as to the desirability of restricting the name Hindu Kush to the mountains east of the Kotal-i-Shibar; employing it in fact for so much of the water-parting as is included between the meridians of 68° and 74°[2].

II.—STRATIGRAPHICAL.

The geology of the Khyber and of the area adjoining that part of the Afghan frontier has been described by Mr. Griesbach (**13**, 89), who recognised five rock-groups, *viz.* (in descending order):—

(*e*) shales and earthy beds;

(*d*) limestones and alum shales;

[1] This is not strictly accurate; the Kotal-i-Hindu Kush really lies to the *east* of the Kotal-i-Chahárdár.

[2] Since the above was written, my attention has been drawn by Major H. L. Crosthwait, R.E., to a paper by Dr. Felix Oswald recently published in *Science Progress* (No. 17, July 1910). The paper deals chiefly with the Himalayan mountains and Tibet, all beyond the scope of the present memoir, but the sketch-map, which faces page 40, includes the eastern part of Afghanistan and shows the Hindu Kush as a series of ranges, the most important of which appears to be a direct continuation of the Koh-i-Bábá; this is drawn as a well-marked line of folding extending along the north-western side of the Ghorband-Panjshir trough and passing at some distance to the north and west of Tirich Mir. Still more striking is the importance given to the Paghman range, which is shown as running continuously in a N.E. direction through Afghanistan, then turning east and south-east to pass through Chitral to Hunza and Nagar and apparently ending near Aling Gangri. To the west of the Kunar river and between Chitral and Kabul an "Archæan Buttress" is made to include the mountainous region of Kohistan and Kafiristan. Unfortunately, Dr. Oswald does not quote authorities on which this re-arrangement of the Afghan trend-lines is based, and I am unable to ascertain whether he has at his disposal more information than I have been in a position to collect. I have already shown, however, that the Koh-i Bábá is not continuous with the range to the north of Ghorband and Panjshir—the true Hindu-Kush—, whilst the Paghman range has, I think, been given undue importance. It is in reality only a comparatively unimportant feature derived from the virgation of the Hindu Kush.

(*c*) metamorphic strata, with graphitic layers;

(*b*) phyllites and schists;

(*a*) gneissic series.

I have not been able to carry this classification of the rocks to the west of the Indian frontier. Mr. Griesbach appears to have regarded his divisions (*a*) to (*d*) as the equivalents of the rocks of the Siáh Koh to the west of Jalálábád, which appear to be the oldest in Afghanistan.

I have divided the rocks of the areas that I was able to visit into the following series:—

Upper Tertiary (? Siwalik).

Unconformity.

? Middle Tertiary of Ghorband.

Unconformity.

Lower Tertiary (? eocene) of Saighán and Káhmard.

Cretaceous limestone and shales.

Unconformity.

Red Grit series.

Saighán series.

? *Unconformity.*

Doáb Volcanic series.

Unconformity.

Khingil series of Eastern Afghanistan.	Fusulina limestone in Northern Afghanistan.

Helmand series.

Hájigak Limestone and Hematite.

Kálu series.

Metamorphic and Crystalline rocks of Kabul and the Siáh Koh.

Of these subdivisions the Khingil series is confined, so far as we know, to Eastern Afghanistan and does not extend up to the Hindu Kush, at any rate west of Kohistan. It may possibly extend into that

range in the latter district and in Kafiristan, but the geology of these areas is quite unknown.

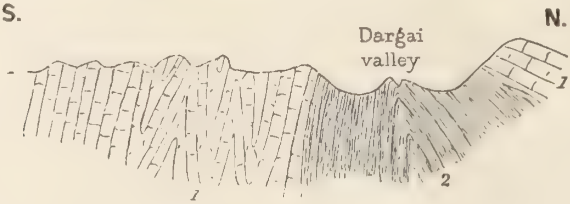
Metamorphic and Crystalline Series.

The Siáh Koh was described by Mr. Griesbach (**13**, 70) as consisting of metamorphic rocks—mica and hornblende-schists with crystalline ruby-bearing limestone—overlain by darker, sometimes comparatively unaltered, limestone, which he referred to the Carboniferous system. My observations were confined to the western part of the range in the neighbourhood of Jagdallak, but I was able to make an almost complete traverse across it from north to south and, as the strike of the beds is E.-W., I saw a section of the whole series. This corresponds well with the section given by Mr. Griesbach, and consists in the main of biotite-gneiss and hornblende-mica-schist overlain by a thick series of crystalline limestone. The whole series is greatly disturbed and the relationship between the schists and the crystalline limestone very obscure. On the south the limestone is in contact with biotite-gneiss—at times biotite-schist—which is pierced by a network of granite veins. The direction and dip of the foliation planes of the gneiss are very irregular and it is difficult to say whether the rock underlies or overlies the limestone.

On the north side of the Pari dara, the famous defile near Jagdallak, hornblende-schist is found interbedded with the limestone and in the defile itself biotite-gneiss and schists (biotite- and hornblende-) appear to alternate with the limestone beds. Further to the north-east, however, in the small plain in the Dargai valley, the belt of crystalline limestone is clearly underlain by a series of hornblende-mica-schist and quartz-schist forming an anticline with its crest leaning over to the south.

At first sight the limestone belt appears to consist of a regular ascending series of almost vertical beds of crystalline limestone with occasional bands of schist interstratified, but a closer examination

reveals the presence of a number of compressed anticlines, and the whole series has evidently been repeatedly folded (fig. 3). Even in the



1, Crystalline limestone ; 2, Schist.

FIG. 3.

Folded crystalline rocks of the Ruby mines.

individual beds of crystalline limestone the dip is very capricious, and a band, which was dipping to the south at one point, was found at a few hundred yards further along the strike to be dipping to the north.

The crystalline limestone is quite the most interesting of the rocks of the Siáh Koh, and bears a close resemblance to the similar mineralised limestones of India and Burma. The number and variety of the accessory minerals is not perhaps so large as in the limestones of Mogok and Sagyin, nor is the size of the individual crystals of these minerals so great, but otherwise the two are very much alike. The commonest minerals in the Jagdallak marble are phlogopite, graphite, chondrodite, spinel and garnet; here and there also pyrite, muscovite and corundum in the form of ruby or, rarely, sapphire. A marked point of difference, however, is the almost complete absence of pyroxene-gneiss, pyroxene-granulite and khondalite (quartz-garnet-graphite-sillimanite schist). Only one of these rocks has been observed and that in quite insignificant quantity. In one locality, at about 4 miles to the east of Jagdallak, of small band of pyroxene-granulite was observed in the crystalline limestone. The beds are vertical and the limestone contains hornblende-biotite schist and biotite-granite in thin parallel bands The granite is of the augen gneiss type but is clearly intrusive; the schist may be due to the metamorphism of arenaceous bands interbedded with the

limestone or may represent apophyses from the granite. The band of pyroxene granulite is only about two inches thick and passes away into limestone on one side and granite and schist on the other; it contains a great deal of sphene and has all the appearance of a contact product due to the interaction of the granite and the limestone. The development of the numerous accessory minerals in the limestone is clearly due to the effect of the intrusion of the granite, since these minerals are always most numerous at the junction of the two rocks. The most highly mineralised parts of the limestone are, in fact, associated with narrow ribbons—two or three inches thick—of decomposed rock consisting chiefly of quartz, felspar and biotite; these might be called either biotite-gneiss or biotite-schist, and appear to be apophyses from the foliated augen gneiss—originally a granite—which is intimately infolded with the crystalline limestone.

To the south, the limestone belt is succeeded by the schists already referred to (*supra*, p. 11) and which appear at one time to overlie, at another to underlie, the limestone. These again give place to a belt of pegmatite, which is younger than the schists. It is of the ordinary Himalayan type and is composed of quartz, felspar, muscovite (in fairly large crystals), some schörl and beryl. The pegmatite band is about 100 yards wide where it was crossed by me: it appears to run eastwards for miles along the Siah Koh approximately parallel to the strike of the schists and crystalline limestone. To the south of this pegmatite, another limestone series occurs and probably forms much of the high ranges between the Jagdallak ruby mines and Surkhpul. In the immediate neighbourhood of the pegmatite it occurs in thin flags at first white, then—a little further off—yellowish and ferruginous; still further away it is grey and occurs in thicker beds associated with phyllite and quartzite. The grey limestone contains small patches of calcite and occasionally streaks of hematite. This limestone series is quite different in appearance to, and much less highly metamorphosed than, the mineralised crystalline limestone described above; it is, however, schistose and distinctly metamorphic.

The general characters of the highly mineralised crystalline limestone of the Siah Koh are so similar to those of the spinel- and corundum-bearing limestone of Mogok, that it is difficult to avoid correlating the one with the other, and the temptation to include the Jagdallak rocks in the Archæan system is almost irresistible. Mr. Griesbach, on the other hand, regarded them as metamorphosed calcareous sediments of Carboniferous age. Towards the eastern end of the Siah Koh, he found crystalline limestone associated with a grey limestone containing crinoid stems. I think there can be no doubt that the grey limestone referred to is the same as that found by me to the south of the belt of pegmatite; I certainly found no fossils in it, but it containedr ods of white calcite such as one often finds in old metamorphosed and foliated limestones.

Mr. Griesbach's specimen from Kala-i-Sher is apparently perfectly identical with the above rock; it also contains rods of calcite, which I was inclined to attribute to metamorphism, but, on polishing the rock, I found that these rods undoubtedly represent fragments of crinoids, one of which is a portion of a stem with a quinquelobate axial canal. Evidently, therefore, we are dealing with something very much younger than Archæan; and if the association of the grey limestone with the ruby- and garnet-bearing rock is such as Mr. Griesbach supposed, the age of the highly mineralised limestone of Jagdallak must be approximately that of the crinoids. In this connection it will be advisable to quote Mr. Griesbach's remarks in full; he says (**13**, 70) :—

"A section through the Siáh Kóh from south to north presents what appears to be an unbroken sequence of strata. Near the middle of the range, at Báb-i-Kach, a belt of considerable width (at that spot about six miles wide) is formed by a series of metamorphic strata, chiefly mica and hornblendic schists with talcose phyllites. Some beds of finely crystalline grey gneiss beds occur in this series, but on the whole the character of the zone is more schistose. This series is overlaid by highly altered strata, principally limestone beds, within which the old ruby mines of Jagdallak are situated.

"The limestone belt is quite conformable with the underlying schists and, with them, has a rolling dip to the north and north-east.

The limestone belt may be traced across the Pari Darra (see above), from thence across the high Jagdallak hills, through which it takes an almost due easterly course

to Amluk at the foot of a high crest, which rises in the Amluk peak to 7,790 feet; it runs from that locality always at the southern slope of the main crest of the Siáh Kóh to the Gachao peaks, south-east of which it crops out in the valley of the Súrkháb (river). It may be seen all along the scarp on the left side of the river as far as the Doronta gorge of the Kábul river, and thence strikes across into the hills which form the Besúd and Kúnar ranges. This belt of limestone beds is economically important on account of the rubies which are found within it. They occur in a highly crystalline, coarse marble, which contains mica as accessory mineral; garnets and spinel occur with rubies throughout this belt, but at a few spots are accumulated in nests as it were, and then the entire rock is tinted a pink colour with the minute crystals of these minerals. With the schistose beds below the belt is closely connected both stratigraphically and mineralogically, several thin beds of crystalline limestone being seen interbedded with the mica schist below.

"South-west of the Doronta gorge, near Kala-i-Sher, the section through the limestone is well exposed in most of the small ravines which cut through the scarp. I noticed that resting on the base of metamorphic schists are highly crystalline limestone beds in flags, with shaly partings: the limestone, though crystalline, has preserved its stratified structure perfectly. It is dotted with small rusty spots, which, I believe, owe their origin to decomposed garnets, which in other localities are common throughout the belt. Besides this it is highly characteristic of these limestone beds that white mica in small leaflets occurs in profusion along the plane of stratification throughout.

"Some distance higher in the section near Kala-i-Sher I observed some 40-50 feet of this limestone band almost unaltered and formed by dark grey hard limestone in which indistinct fossil impressions are visible with many fragments of *crinoids*. The whole appearance of the limestone reminded me of much the dark *crinoid* limestone of the Hindu Kush, which also is associated with metamorphic strata—a limestone which I have placed in the carboniferous system.

"The beds above this fossiliferous limestone are much more altered, and are in fact converted into very fine white marble, fine grained and almost structureless. It is now being worked as a statuary marble by the Amir's people. Even in this marble isolated leaflets of mica are discernible, whilst higher up in the section the marble becomes very coarsely crystalline, which then contains much mica.

"The entire thickness of the limestone zone cannot be less than about 3,000 feet in this section."

It would appear from this that the ruby-bearing limestone is closely associated in age with the crinoid limestone of Kala-i-Sher and if we accept Mr. Griesbach's conclusions, we must follow him, not perhaps in referring the beds to the Carboniferous system but in basing an estimate of their age on that of the crinoids. Unfortunately, these are not sufficiently characteristic for determination; possibly, however, the rock corresponds to the crinoid limestone of the Waghzar valley in Ghorband

(*infra*, pp. 25, 48), in which case its age will be approximately Devonian.

It is certainly difficult to accept the crystalline schists and limestones of Eastern Afghanistan as of Devonian age; yet if we accept Mr. Griesbach's views as to the gradual passage in the Siah Koh from one formation into another and the absence of any break in the sequence except between the crystalline limestone and the overlying 'gneiss,' there is no escape from such a conclusion, and it will be necessary to regard all the rocks of the Siah Koh as post-Cambrian. On the other hand, Mr. Griesbach does not appear to have been himself entirely convinced as to the age of this metamorphic complex, for he has referred to it in one place as "formed of old crystalline rocks, amongst which there may possibly be some palæozoic outliers." The 'old rocks' here may mean his so-called 'gneiss,' which, however, is really a foliated biotite-granite similar to, and probably of the same age as, that of the Himalaya.

At the western end of the Siah Koh, the grey limestone, which is presumably the same as Mr. Griesbach's crinoid limestone, has not been found in direct association with the ruby-bearing rock, but is separated from it by a belt of pegmatite, which may quite well represent an important physical break; it is conceivable that intrusion has taken place along a fault or a thrust-plane, and the approximate juxtaposition of the two limestones would not, therefore, necessarily imply any association in time. Mr. Griesbach's study of the whole range, however, was much more extensive than any that I had the opportunity of making, and he makes no mention of any break in the succession; nevertheless the amount of disturbance to which all the rocks in this area have been subjected is so great that the apparently uninterrupted sequence may quite possibly include an overthrust which has escaped detection owing to the uniformity of dip throughout the section at Kala-i-Sher.

Turning now westwards we find another series of metamorphic rocks in the Kabul valley, in Logar and in parts of the Paghmán range. It

consists of gneisses, crystalline schists and limestones, and forms the ranges bordering the Kabul plain on the south, including most of the small hills at Charásia, and the range separating the Kabul valley from Masai. This range is cut through by the stream which flows from Khurd Kabul past Butkhak to join the Kabul river at Pul-i-Charkhi, but the rocks continue on the opposite side of the gorge and form the lower half of the high hill ("Khurd Kabul" station, 11,113 feet) which overlooks Khurd Kabul on the north.

Between the Kotal-i-Munár, on the same range, and the conspicuous peak Shákh-i-barant (8,935 feet), the prevailing rocks are mica-schist, quartzite, schistose crystalline limestone and various intrusive igneous rocks, including diorite and granite. Shákh-i-barant itself consists of an igneous complex below capped by thin-bedded and intensely folded limestone. On the hill-side, behind the upper village of Keshlák, a thin bed of hematite, associated with schistose hematite-quartzite, occurs among the schists and limestones.

A thick bed of the same rocks, associated with limestone and hornblende-schist, evidently a continuation of the Kabul series, is recorded by Captain Drummond as occurring a few miles away on the Silawat Pass to the east of Katasang (**5**, 75).

To the south and west of Kabul, the famous hills, Sher darwaza and Asmai, at the foot of which the city stands, are composed of thinly foliated hornblende-biotite-gneiss associated, near Indaki, with epidiorite, an old and massive intrusion, quartz-garnet-actinolite rock and garnet-sericite schist. The two latter are presumably altered sediments; the quartz-garnet-actinolite rock is very like certain rocks found in the Haimantas in Spiti and in the Carbonaceous system near Simla, and which have been produced by the metamorphism of a sandstone or a quartzite by a basic (dioritic) dyke.

The same series of crystalline rocks extends over the whole Kabul plain, cropping out here and there from below either the alluvium or the Upper Siwalik sands and conglomerates. It probably forms also much of the Paghmán range, particularly the southern part between Arghandi and Shakar dara.

At about 4 miles to the north of Kabul, across the *chaman*[1] and near the village of Khoja Bogra, is a small hillock of crystalline limestone with a little gneiss and some bands of epidiorite. The limestone is interesting as containing bowenite, the hard variety of massive serpentine. It is apple-green in colour and the large patches, several inches in width, show up very beautifully on the background of white and creamy marble.

Age of the crystalline series.

Like the metamorphic rocks of the Siáh Koh, those of Kabul present a difficult problem in the determination of their age. Assuming that between the Asmai heights and Khurd Kabul we are dealing with a single group of rocks, we have at least the means of fixing an upper limit to their age, for they are overlain unconformably on "Khurd Kabul station" (11,143 feet) by fossiliferous Upper Palæozoic (Upper Carboniferous or Permian) limestone (*infra*, p. 21). They cannot, therefore, be younger than Carboniferous. In the other direction, however, there is no limit assignable. The unconformity is very pronounced, and the overlying fossiliferous limestones show no signs of metamorphism; presumably, therefore, the schistose series had already been metamorphosed before the Upper Palæozoic transgression took place, and one would naturally conclude that the difference in age represented by the unconformity is very considerable. Other considerations also lead us in the same direction, and one is tempted to see in the cupriferous mica-schists and limestones and in the quartz-hematite schist of Keshlak in Masai, representatives of our Indian Dharwars.

On the other hand, the resemblance of this crystalline series to the Dharwars is no greater than that of the Jagdallak limestones to the corresponding members of the Archæan group in the Peninsula and Burma, and if we are to follow Mr. Griesbach in regarding the rocks of the Siah Koh as Palæozoic, we may equally well refer the crystalline schists and gneisses of Kabul to the same group. Justification for such a course might perhaps be sought in the conditions prevailing in the

[1] A broad reedy swamp.

Hindu Kush in this part of Afghanistan. At the northern end of the Paghmán range, the ridges behind Charikár are composed of biotite-gneiss and granite capped by crystalline limestone; the latter contains mica and coccolite and is overlain by a grey saccharoid marble with lenticular patches of calcite, evidently a sedimentary rock altered by the numerous veins of schörl-granite by which it is penetrated. These rocks in some respects resemble those nearer Kabul, but the biotite-gneiss appears fresher and more like the common foliated biotite-granite of the Himalaya. Rock-types very similar to the limestones have been produced, only a few miles away across the Ghorband river and on the same line of strike, by the action of the granite of the Hindu Kush on an undoubted sedimentary series of post-Cambrian age. On this basis the hematite of Masai might also be claimed as the representative of the similar rock of the Koh-i-Bábá and Ghorband (*infra*, p. 24).

The advanced state of metamorphism of some of the sedimentary beds in Ghorband and Parwán certainly led me at first to regard them as Archæan, but convincing evidence, subsequently obtained, proved them to be comparatively young and not older than Lower Palæozoic. It must be admitted therefore that it is equally possible that the crystalline rocks of Kabul are the result of an analogous set of phenomena and merely a more advanced stage in the metamorphism of similar post-Cambrian sediments.

It is clearly impossible, on such facts as are at our disposal, to attempt to estimate the age of the crystalline rocks of Kabul and the Siah Koh. On the one side, we have petrological evidence pointing to the Indian Archæan group, whilst, on the other, palæontological evidence suggests the Palæozoic. A third point of view is the tectonic, and from this Mr. Griesbach (**13**, 66) and Professor Suess (**29**, 291) have assumed that an Archæan mass, lying between the Hindu Kush and the Safed Koh, is accountable for the difference in trend between these two regions. Mr. Griesbach writes :—"This was land, when the partly littoral, partly fresh-water, beds of the trias (with coal) were laid down in the basin of Kataghan and Áfghán Turkistán, and formed a rigid

mass to a certain extent, against which the sedimentary formations of the mesozoic and tertiary times were forced and thus laid into the folds which now form the greater area of Central Asia and the fringing ranges north of the Hindu Kush." Since, according to Mr. Griesbach, Tertiary beds are involved in this folding, the age of the postulated *horst*[1] need not be greater than late Cretaceous or early Eocene, and it will be shown below (p. 22) that at least part of it was submerged during the Triassic period.

The metamorphic area extends from Kabul for considerable distances in all directions. On the south Mr. Griesbach found hornblende- and mica-schists and crystalline limestone, often associated with igneous rocks, in Logar, Kharwar, Khurd Kabul and in the upper valley of the Surkh-ab. The metamorphic series is associated, in some manner which is not quite clear, with a grey limestone which Mr. Griesbach referred to the Mesozoic group and which is extensively developed in the neighbourhood of the Shutargardan *massif*, and extends along the southern flanks of the Safed Koh (**13**, 74). To the south-west of the Shutargardan the same metamorphic series is largely developed in Kharwar, where the sequence is said to be the same as that of the Siáh Koh (**13**, 77).

[1] In Mr. Griesbach's view this was a continental area of old crystalline rocks, and is not to be confused with the deep-seated *horst* which has recently been placed by Professor Joly on the geological *Index expurgatorius*. This is presumably the "Archæan Buttress" inserted on Dr. Oswald's map referred to above (footnote, p. 9). From my description of the Khingil series (p. 22), it will be seen that much of this supposed "Buttress" is composed of marine Trias of Himalayan type. The difference in direction between the lines of folding of the Hindu Kush and those of the Safed Koh does not require the postulation of any intervening obstacle, for their respective trends are only such as would be expected from the nature of the syntaxis of the Himalaya with the mountains of Afghanistan, resulting in a curve convex to the north, and produced apparently by the lapping of the southward-moving folds around a projecting cape of Gondwanaland. The area occupied by this so-called buttress has never been visited by a geologist, and consequently we have no direct evidence as to the nature of the rocks of which it is composed, but from such observations as I was able to make from neighbouring hills, I have little doubt that it embraces partly the easterly continuation of the rocks of the Kabul plain and partly beds similar to those of the Paghmán and Hindu Kush ranges, whilst direct observations show that some of the hills are capped by the comparatively young rocks of the Khingil series.

To the north and west of Kabul metamorphism has affected the rocks for considerable distances, even as far as the summits of the Hindu Kush in the one direction and up to the Helmand in the other. As we pass outwards from Kabul, however, it becomes gradually less intense and more local. In the upper reaches of the Kabul river, the schists of Masai are replaced by slate and phyllite, but crystalline limestone is still common, and the small amount of marble that has been used for ornamental purposes in Kabul, as in the construction of the mosque in the Bágh-i-Bábar, is said to have come from Maidán (**18**, 345).

Khingil Series.

Before leaving the Kabul area, it will be as well to refer to the only extensive series of fossiliferous rocks found in that part of Afghanistan. It has already been pointed out that the high range between Butkhak and Khurd Kabul consists of Upper Palæozoic and Mesozoic limestones overlying the crystalline schists. A careful examination of these limestones would certainly yield valuable results. Unfortunately I was unable to attempt this, as I could only devote a single day to the hill range. The highest point is 11,143 feet above sea level, over 5,000 feet above Butkhak and a little less above Khurd Kabul. I climbed over the ridge from the Khurd Kabul side a short way below the summit, but was so delayed by detours round inaccessible cliffs that it was late in the day before I reached the ridge and I could only devote a very short time to searching for fossils during the difficult descent on the other side. On the north-western side, however, I found limestones and interbedded shale, with badly preserved ammonites and lamellibranchs, which appear to include *Meekoceras* sp., *Ophiceras* sp. and *Pseudomonotis* sp. Specific determination is out of the question and even the genera are doubtful, but the general appearance of the rocks and fossils is so exactly characteristic of the Lower Trias of the Himalaya that anyone familiar with that stage could not fail to be struck by the resemblance.

Below these fossiliferous beds is grey limestone followed lower down by darker limestone full of sections, in white calcite, of large brachiopods, probably *Spirifer* sp. Lower down again is another band of limestone containing many small *Producti;* but the matrix of all these fossiliferous bands is so hard that I could get out nothing specifically determinable. With time to follow the beds along the hill-side, it would no doubt be possible to find recognisable species. Even my very hurried inspection, however, suggests strongly the presence of the Himalayan Trias and the Productus Limestone, thus linking the Kabul area with Kashmir on the one hand and the Bazar valley (**15**, 111) and, indirectly, the Salt Range on the other.

This limestone series probably covers most of the ranges on the east of the Kabul plain. It was at first taken by Mr. Griesbach for the Upper Cretaceous limestone of Turkestan (**10**, 23), but he subsequently recognised that it was older (**13**, 69) although absence of fossils prevented his determining its age. What is probably an inlier of the same series occurs among the Tertiary beds to the west of Sarobi where it contains *Megalodon* sp. and ? *Dicerocardium* sp. and is absolutely identical in appearance with the Megalodon limestone in the Para stage of the Himalayan Trias (**16**, 84). The series thus appears to range in age from Carboniferous to Upper Trias at least and possibly higher. It cannot yet be subdivided and must be dealt with for the present as a stratigraphical unit under a single name. As it caps, and probably forms the greater part of, the Khingil range on the east of the Kabul plain, it might be conveniently named the "Khingil series", a term which may be discarded as soon as it becomes possible to subdivide it into smaller units.

Locally the limestone has been considerably altered by igneous intrusions, chiefly of granite and serpentine. The Khingil series appears to extend from Khurd Kabul across the Lataband and the Kabul river, and probably forms most of the hills between the eastern edge of the Kabul plain and the Panjshir river. To the south-east it may form the Karkacha range in Tezin; this assumption, however, is

only based on an examination of the range through glasses from the top of Khurd Kabul hill and may be erroneous. Nevertheless, the series certainly covers an extensive area in Eastern Afghanistan and probably runs on through the Safed Koh to Chura and the Bazár valley.

Kalu Series.

Leaving the metamorphic region of Kabul and turning northwards and westwards to the Hindu Kush and Koh-i-Bábá, we find a number of groups of sedimentary rocks extending far to the north through Saighán and Káhmard to the Oxus. Much of this area is covered by a cloak of Cretaceous limestone, which lies unconformably on all older formations, but in Ghorband, Bámián and the upper part of the Helmand basin, Palæozoic beds predominate, and comprise the greater part of the Hindu Kush and Koh-i-Bábá. Between the Kotal-i-Hájigak and Bámián the latter range consists of a series of thinly-foliated gneiss, schist, quartzite and slate, which extends from the Paimùri gorge to beyond Kálu. With these rocks, at about 4 miles below Kálu, are associated thick beds of conglomerate. To the east and north-east of the caravansarai (*robát*) of Kálu, the hills are composed of slates often dark and carbonaceous (graphitic). The whole series recalls the Haimantas of the Himalaya, but in the absence of fossils we have no direct evidence as to its age. Its stratigraphical relations are not clear and my traverse was too rapid to permit of my working them out, but the series appears to be overlain by a bed of hematite followed by limestone, which, at the western foot of the Kotal-i-Hájigak, contains a fauna probably of Devonian age (see next page). We may therefore assume—if we are right in regarding it as older than the limestone—that the Kálu series represents the lower part of the Palæozoic group.

The only other locality in which this series has been recognised is the Ghorband valley, where gneiss, schist and graphitic slate form the walls of the gorge through which the river debouches on to the plain of Koh-i-Dáman. Between the gorge and Asháwá the valley

follows approximately the crest of an anticline, and the Kálu series is found on both sides of the river.

Hajigak Limestone and Hematite.

The graphitic slates in the neighbourhood of Kálu (Plate 4) are apparently overlain by a thick bed of hematite, which can be seen for miles capping the high ridge which runs north-eastwards towards Ghorband. On the southern flanks of this ridge, the hematite is overlain by slate which, in turn, is overlain by grey limestone with calcite veins and numerous small crystals of hematite; this is associated with a fossiliferous, black thin-bedded limestone. An outcrop of the latter limestone is seen at the edge of the road, just at the foot of the Hájigak pass, where a stream flows down from the north. Fossils are numerous in this small outcrop; they are chiefly brachiopods including *Spirifer* cf. *Verneuilii* Murch., *Strophalosia* sp. and *Rhynchonella* sp. The grey limestone seen higher up the hill-side contains corals, including the genera *Zaphrentis* and *Syringopora*; with these I found a few fragmentary brachiopods, similar to those occurring in the higher beds, and part of the thorax of a trilobite. The black limestone is probably Devonian and thus gives us a datum line to work from.[1] At the same time, the hematite bed is a most characteristic horizon and, being readily recognised where the overlying limestone is either unfossiliferous or metamorphosed, is an invaluable guide in the elucidation of the complicated structure of Ghorband and the Hindu Kush.[2]

[1] Since writing the above, I have heard from Mr. F. R. Cowper Reed, who has kindly examined the specimens for me, that the fossils of the black limestone are Upper Devonian and those from the grey limestone Lower Carboniferous. A description of them, by Mr. Cowper Reed, will shortly be published in the *Records* of the Geological Survey.

[2] In view of the presence of hematite associated with Devonian limestone in the Koh-i-Bábá it is interesting to note that the magnetite beds of Mt. Magnitnaïa in the Southern Urals are regarded by Nicolaew as derived from Devonian deposits. He believes the magnetite to have arisen from the alteration, by eruptive rocks, of hematite or spathic iron the origin of which, he further suggests, may perhaps be sought in the action of ferruginous or siliceous solutions on a limestone, probably of Devonian age (**22**, 670).

From slightly below the village of Siah-gird in Ghorband the hematite, associated with a red limestone, runs all along the lower slopes on the left side of the valley past Kaoshán to Ashává, where the strike (N.E.-S.W.) carries it across the lower spurs of the Hindu Kush to Parwán. Thence it runs on up the Panjshir valley into the hills of Kohistán.

In the Ghorband valley, the hematite bed is overlain by a crystalline series consisting of slate, schist and limestone, which presumably represents the Hájigak series; the only fossils found in it were crinoid stems, which occur in profusion in the Waghzar ravine, but as the limestone has been metamorphosed and is quite crystalline, the fossils are not determinable.

Helmand Series.

Along the north-western side of the Paghmán range, in the Sanglákh range throughout the upper reaches of the Helmand and again in the Koh-i-Bábá, there is a very extensive series of slate and quartzite, the beds of which are often vertical or dip at high angles to north or south. It is well seen in the Helmand basin between the *col* at the head of the Kabul river (Kotal-i-Unai) and Kharzar at the foot of the Kotal-i-Hájigak on the Koh-i-Bábá and may be called for convenience the Helmand series. In places intrusive granite has converted the slate into phyllite with chiastolite and occasionally into well-defined schist; this has occurred between Gardan Diwál on the Helmand and Jaokul. Here the series contains also limestone which has been converted by the granite sometimes into calc-schist and sometimes into a grey saccharoid marble. On the west side of the Kotal-i-Unai, on the water-parting between the Helmand and Kabul rivers, a conspicuous member of the series is a dark greenish, compact but fairly coarse conglomerate.

The relationship of the Helmand series to other series in this area is very obscure. On the Kotal-i-Hájigak, above Kharzar, it appears at one time to overlie and at another to underlie the Hájigak limestone which is probably of Devonian age. In the Ghorband valley, however,

to the south of Siah-gird, the beds dip at high angles to the north-west and thus appear to underlie the crinoid limestone of Waghzar which I regard as the continuation of the Devonian beds of the Kotal-i-Hájigak.

In the Parsa valley, on the other hand, the same rocks continue with a steady south-easterly dip right up to the granite which forms here the crest of the Paghmán range.

On the opposite side of the Ghorband valley, the crest and south-eastern slopes of the Hindu Kush consist largely of slate, schist and quartzite. Good sections of these are seen on the way up to the Chahárdár pass and on the heights at the head of the Jú-i-dukhtar.[1] Metamorphism by the granite is very general here, and correlation can be only tentative, but I am disposed to regard these rocks as a metamorphic facies of the Helmand series.

In the hills between Bámián and Saighán, there is a similar series of slate, schist, graphitic schist and quartzite, which may represent the Helmand series with perhaps some of the underlying horizons. Like the sections in Ghorband those in Saighán are obscured by intrusive granite, and one cannot refer these beds confidently to the Helmand series. The graphitic schist rather suggests the Kálu series, but I have not observed any representative of the hematite bed.

In the neighbourhood of Ak Robát, the rocks which I have referred to the Helmand series are overlain by crinoid limestone which contains Fusulina, and is probably of Upper Carboniferous age. The Helmand series is therefore presumably Lower and Middle Carboniferous, and fills the gap between the Hájigak and Fusulina limestones.

Fusulina Limestone Series.

From the middle of the Ghorband valley above Siah-gird to Ak Robát in Bámián, there is a continuous belt of limestone and slate For the most part the limestone is a dark grey, more or less crystalline rock with numerous veinlets of calcite. No fossils have been found in it in Ghorband, and I consequently refer to it in that valley as the

[1] *Ju* or *Juy* = a stream (*Pers.*)

'Ghorband limestone', but between the Shibar pass and Balula and again in the mountains on the north side of the Bámián valley, parts of the limestone are full of *Fusulina* and *Schwagerina*, which define the age of the rock as Upper Carboniferous or Permian. Fusulina limestone occurs again on the Ak Robát Kotal on the road from Bámián to Saighán. In this area it is associated with the grit, quartzite and slate that I have referred to the Helmand series. On the ascent to the crest of the range behind the Ak Robát caravansarai, the limestone is underlain by a thick bed of conglomerate. A similar rock occurs at Shumbal in huge blocks lying on the limestone, but was not found *in situ*.

In the Khwájagar ravine in Bámián the Fusulina limestone series consists of a massive, apparently unfossiliferous rock overlain by a small thickness of slate and quartzite, followed by shaly thin-bedded limestone containing large numbers of *Fusulinæ*, including *F. elongata* Shumard and *F. uralica* Krotow. With this is associated a band of compact black limestone containing brachiopods, of which the commonest is *Productus punctatus* Mart.; other genera are *Reticularia* (*R. lineata* Mart.), *Dielasma, Uncinulus* and *Spirifer*. Above this is a thin band of coral limestone, succeeded by more limestone with *Fusulina* and a thick mass of pale grey limestone containing large numbers of *Schwagerina*.

The *Fusulinidæ* of these limestones comprise the following species :—

Fusulina uralica Krotow.
„ *elongata* Shumard.
„ sp. indet.
Schwagerina princeps Ehrenberg (including *S. verbeeki* Geinitz).
„ (*Doliolina*) *lepida* Schwager.
Neoschwagerina craticulifera Schwager.
„ *primigena* Hayden.
Sumatrina annæ Volz.

In addition to these there are many other foraminifera, most of which have been observed only in thin sections under the microscope

and cannot be determined with any confidence. They include, however, species of *Miliolina* not yet described, *Spiroloculina* sp., and various genera of *Textularidae*, including *Bigenerina* d'Orb. and *Valvulina* d'Orb. (= *Tetrataxis* Ehr.).

Douvillé recognises three zones in the Fusulina limestones of the Indo-China and S. E. Asia,[1] viz.:

(1) Upper Permian, with *Sumatrina annæ* Volz, (2) Lower Permian, with *N. craticulifera* Schw., and (3) Uralian, with *Schwagerina princeps* Ehr. All these are represented in the limestones of Afghanistan, which we may therefore regard as extending from Carboniferous to Upper Permian.

Outcrops of massive grey limestone are common among the hills between Ák Robát and Saighán and also westwards in the Ao and Khárgin valleys. Fossils have not been found in any of them, but I have little doubt that detailed examination of the rock under the microscope would enable us to refer most of the apparently disconnected occurrences to the Fusulina limestone and associated limestones of Ghorband and Ák Robát.

Doáb Series.

Neither in the Shibar area nor on the Koh-i-Ghandak was I able to examine the beds immediately overlying the Fusulina limestone series, but in the latter area it is probably overlain unconformably by Upper Mesozoic rocks.

In upper Saighán the older formations are overlain unconformably by a volcanic series, which covers a large area both there and in lower Saighán and is evidently younger than the Fusulina limestone. It may be conveniently named the 'Doáb series,' being well exposed at and around Doáb-i-Mekhzarín at the junction of the Káhmard and Saighán rivers. It consists of volcanic ashes, breccias and lava flows with interbedded shale and sandstone. Shale is usually more prevalent in the

[1] *Bull. Soc. Géol. France,* 4e Sér., VI, 587 (1906).

upper part of the series. Conglomerate occurs locally and in one locality a coarse volcanic agglomerate was noticed.

The age of the series is doubtful, as no conformable junction with underlying rocks has been observed, and it has been found, in upper Saighán, distinctly unconformable to the supposed Fusulina limestone. On the other hand it sometimes appears to be overlain conformably by a plant-bearing series of middle Jurassic age (the Saighán series). How far this appearance may be deceptive I have not been able to determine; in certain places there is apparently a well-marked unconformity between the two series. The Doáb series, however, is evidently partly of marine and partly of sub-aërial origin, whilst the Saighán series appears to have been deposited in fresh-water; this would fully account for the apparently anomalous mutual relations of the two series and there is no conclusive evidence of any serious time-break between them. Consequently the Doáb series is probably partly of Jurassic and partly of Triassic age. No fossils have been found in it in any part of the area that I visited, although some of the dark shales seem admirably suited for their preservation; but it is possible that certain lamellibranchs collected by Mr. Griesbach in Chahil, may have come from it (see *infra*, p. 31). It is unfortunate that I had no opportunity of ascertaining the relationship of this series to the fossiliferous beds of the Fusulina limestone; in several localities which happened to be accessible to me I had hoped to find both series, but they were hidden at the crucial point by the cap of Upper Cretaceous limestone which covers so much of this part of Afghanistan, lying unconformably on, and hiding, all older formations. The most favourable locality would probably be the deep river-gorge between Bámián and Saighán, which I was unable to visit and which is said to be passable only in the winter when the water is at its lowest.

In connection with the question of the age of the Doáb series, it is interesting to note that the late Dr. A. von Krafft, who visited Darwáz in the year 1898, met with a volcanic series of which the lowest beds were interstratified with Fusulina limestone. From the writings

of Weber and other Russian geologists it would appear that similar conditions prevail in other parts of Russian Turkistan and it would not be unreasonable to assume that they extended also into Saighán which is only a little over two hundred miles to the south-west of Darwáz. The Darwáz volcanic series was regarded by Dr. Krafft as Upper Carboniferous and this naturally suggests correlation with the Panjál trap of Kashmir, which Mr. Middlemiss has now shown to be also of that age. One is therefore tempted at first to regard Kashmir, Darwáz and Saighán as local centres of activity along an Upper Carboniferous volcanic belt. The Doáb series, however, appears to be much more intimately connected with the overlying Saighán series than with the Fusulina limestone and such evidence as we have at present points to Upper Trias or Lias rather than to Lower Trias or Permian.

Saighan Series.

With the exception of the Cretaceous limestone this is the most extensive series seen to the north of the Hindu Kush in Saighán and Káhmard; while the Cretaceous limestone caps the hills, the plant-bearing shales, sandstones and conglomerates occur in the valleys. It can be traced at intervals throughout the valley of Saighán from Begal on the west to Tálá on the east. To the north it is found in the Hájar valley and again in Khorak and Chahil. The pass between Chahil and Áb-i-Khorak was the northern limit of my tour and I was unable to examine the Chahil valley, but both there and in Dara Yusuf it is, according to Mr. Griesbach, very largely developed (**9**, 245). The series consists of shale, sandstone, grit and conglomerate. The shales are often highly carbonaceous, containing well-preserved fossil plants and here and there seams of coal. The arenaceous beds are usually brown and the argillaceous various shades of grey or blue according to the amount of carbonaceous material present; in places they range from almost white to black.

What appears to be a complete and perfectly continuous section of the whole series occurs at Ishpushta on the left bank of the Surkháb —the river formed by the junction of the Káhmard and Saighán

rivers—a few miles below Doáb-i-Mekhzarin (Pl. 5). The lowest bed is a white sandstone, which contains a certain amount of volcanic material. At Ishpushta this bed appears to lie with perfect conformity on the volcanic series, the upper beds of which are grey ashes overlying dark needle shales. The origin of the white basal bed of the plant-bearing series is obscure ; it appears to be an ash deposited in water.

From the apparently perfect passage found here between the volcanic rocks and the plant-bearing series, it may be inferred that the occasional unconformities between the two represent no particular time-break but are only what would be expected in the change of conditions of deposition. The age of this series has not yet been finally determined, but there is little room for doubt that it is Jurassic. The fossil plants collected by me are at present in the hands of Professor A. C. Seward, who has kindly undertaken to describe them. They are to a great extent identical with collections obtained by Messrs. Weber, Nazarow and Bronnikow in Russian Turkistan and recently described by Professor Seward (**25**). By Mr. Griesbach they were regarded as Triassic on account of his discovery at Chahil of a band of shale containing lamellibranchs that he determined as *Daonella lommeli* Wiss. and *Monotis salinaria* Schloth.

He recognises three principal horizons (**9**, 245) which are, in descending order—

(*c*) Sandstone and shale with *Schizoneura*.

(*b*) Sandstone and shale with *Equisetites columnaris*.

(*a*) Calcareous sandstone, with *Monotis salinaria* and *Halobia lommeli*.

Coal seams are stated to occur between (*a*) and (*b*) and (*b*) and (*c*). Some importance attaches to Mr. Griesbach's observations on these Chahil beds, since this is one of the localities at which he believed that he had found Gondwanas, and Professor Suess has embodied this view in his account of the Hindu Kush (**29**, 292). Too much weight should not be attached to this tentative classification, however. Mr. Griesbach states that his highest horizon (*c*) has " a strong resemblance to Upper

Barakars in lithological character." As these beds occur more than a thousand feet above the horizon of the fossils that he referred to *Halobia lommeli* and *Monotis salinaria*, we now know that it is impossible that they could represent part of the Barakar stage, which is entirely Palæozoic. The determination of the lamellibranchs from horizon (*a*) has also been found to require some modification. Unless the sandstone from which they were derived was a very thick one, it seemed to me improbable that two species characteristic of widely separated horizons should occur in the same bed. My colleague, Mr. G. H. Tipper, has kindly examined Mr. Griesbach's specimens for me and confirms my view that neither *D. lommeli* nor *M. salinaria* is represented; he regards them as perhaps related to Upper Triassic *Halobiæ*, but their affinities are uncertain, and they may be even younger. In Frech's *Lethæa Mesozoica* (p. 121) the true stratigraphical position of these beds has been still further obscured by the substitution of "*Daonella indica* Bitt." for Mr. Griesbach's "*Halobia lommeli.*" From the observations that I was able to make on the Sabz Kotal, where my work joined and overlapped Mr. Griesbach's, I have come to the conclusion that the two upper horizons (*b*) and (*c*) belong to what I have called the Saighán series.

In Ao Khorak and on the Sabz Kotal, I found no trace of the volcanic Doáb series, which is presumably hidden everywhere by the overlying plant-bearing beds. Nor does Mr. Griesbach make any mention of its occurrence in Chahil. It is of course possible that the volcanic element may not have extended into this area, and is represented by shales and sandstones similar to those of the Saighán series; but it is apparently quite well developed at the same horizon in Western Afghanistan (**8**, 49). It has not been recorded from Russian Turkistan, where the Jurassic plant beds, which are evidently the same as my Saighán series, overlie Carboniferous volcanic rocks (**32**, 396). It is interesting to note, however, that a plant-bearing series which has also been referred by Professor Seward to the Middle Jurassic (**25**, 48), overlies—supposed post-liassic—volcanic beds in the Caucasus (**25**, 1).[1]

[1] Weber's original paper is not accessible to me.

This Mesozoic volcanic phase would therefore seem to have affected a wide area, and it would be rather surprising to find that Chahil was outside its range. Perhaps Mr. Griesbach, having frequently referred to the presence of igneous rocks in what he regarded as the Trias in other localities, did not consider it necessary to refer to them again or possibly the supposed *Halobiæ* are Jurassic. This, unfortunately, is another of the many points in the geology of Afghanistan that must be left for the future—a distant future, I fear—to decide.

The resemblance, both lithological and floral, between the Saighán series and the plant-bearing beds of Ferghana, Syr Darya and other parts of Russian Turkistan, is so striking that there can be no reasonable doubt that the conditions of deposition were the same in both cases and that the Saighán series belongs to the Angara, rather than to the Gondwana, province.

Mr. Griesbach, on the other hand, regarded Western Afghanistan and Afghan Turkistan as parts of Gondwanaland, for he believed that his "Plant-bearing series" was the exact counterpart of the Gondwanas of India (**11**, 98). This opinion was based (*a*) on the lithological resemblance between the basal conglomerates of Palezkár and the Talchirs, and between the uppermost beds at Chahil and the Barakars (**9**, 245); (*b*) on the supposed alternation of the highest beds of the Fusulina limestone series at Ak Robát with conglomerates of his "anthracite series," and (*c*) on the presence of fossils referred by him to *Vertebraria* and *Schizoneura*. With regard to (*a*), lithological resemblance between such widely separated areas as the Salt Range and Western Afghanistan is at the best a dangerous guide, and it has been shown above that the correlation between the Chahil plant-beds and the Barakars is untenable; (*b*) my observations lead me to infer that the "anthracite series" is older than the Fusulina limestone; (*c*) the fossils on which the first of these determinations is based are only indistinct markings, which are quite undeterminable and might be equally well referred to *Equisetites*, while *Schizoneura* has such a wide range that it is of no value unless its species can be ascertained. Perhaps, therefore, the western beds are after all the same as the northern,

in which case they will be chiefly Jurassic, the lower (volcanic) part being possibly Upper Triassic.

Red Grit Series.

In the neighbourhood of Ishpushta the plant-bearing series passes up through brown pebble-beds into a great thickness of intensely red rocks, consisting chiefly of grit, pebbly sandstone and conglomerate. The same series is found also in the Chahil and Khorak area and in Western Afghanistan, where it was named by Mr. Griesbach the "Red Grit group"; its appearance is very characteristic and it is always readily recognised, forming, as it does, a striking contrast to the white, grey and black beds of the underlying Saighán series. It has been found in Bámián, lower Saighán, Hájar, Káhmard and Ab-i-Khorak. In central Saighán it thins out toward the west and in the upper part of that valley, in Begal and Khárgin, disappears altogether, having been removed by denudation, together with almost the whole of the plant-bearing series, before the deposition of the overlying Upper Cretaceous limestone.

The age of the Red Grit series is probably Cretaceous. I had no opportunity of examining it in detail, but it appears to contain very few fossils. I found some hippurites, however, in a red calcareous bed near the top, so this bed is presumably Cretaceous. Mr. Griesbach regarded the series as partly Jurassic and partly neocomian (**11**, 99); this conclusion, however, appears to have been based on the determination of certain brachiopods that he found in beds immediately below the Red Grit series at Firaimán near Mashhad and regarded as a variety of *Terabratula gregaria* Suess. These specimens are among his collections in the Geological Museum in Calcutta and I have thus been able to examine them: they appear to me to be identical with *Terebratula sella* Sow., a common form in the Lower Cretaceous of Europe. They occur in a matrix composed largely of *Orbitolina;* with these there is also a fragment which appears to belong to one of the *Rudistæ,* possibly *Monopleura.* Presumably therefore the "Firaiman

beds" of Mr. Griesbach are Lower Cretaceous and may correspond approximately to the Barremien stage; the Red Grit series must therefore be younger.

Cretaceous System.

This comprises by far the most widely distributed group of rocks in Afghanistan to the north of the Koh-i-Bábá and the Hindu Kush. To anyone looking northward from either of these mountain ranges the whole country appears to consist of gently undulating downs with here and there a small limestone scarp, and it is only when one begins to cross the downs that this appearance is found to be highly illusory, for at every few miles they are cut up by deep valleys, from a few hundred yards to a mile in width and as much as 2,000 or 3,000 feet deep, running approximately east and west and connected with one another by narrow precipitous gorges.

From the Koh-i-Bábá and the Hindu Kush northwards to the plains of Afghan Turkistan, the whole area was formerly covered by a sheet of Upper Cretaceous limestone, which was deposited unconformably on all older formations. At first sight, this appears to lie in almost horizontal beds and we conclude that there has been but little post-Cretaceous crust-movement; but when we descend from the undulating plateaux into the valleys we see at once that this first impression is quite erroneous and that the horizontality of the beds is to be ascribed to the considerable folding that they have undergone. This apparent paradox arises from the type of structure—the recumbent fold—which persists throughout the whole area. Fig. 1 (p. 3) shows diagrammatically the prevailing tectonic conditions, which are also exemplified in Plates 2, 3 and 6. It will be seen that the valleys are cut out along the broken anticlinal crests, whilst the high intervening plateaux are formed by a limb of the recumbent fold. Sometimes the inversion is combined with overthrust along the middle limb of the fold as at Dasht-i-Safed in Káhmard (fig. 2, p. 4).

As a rule the junction of the Upper Cretaceous limestone with all underlying formations occurs on a violent unconformity (see Plate 7), but at Painguzar and again in the Astar-áb valley, both of which localities lie to the north of the Tirband-i-Turkistan, Mr. Griesbach considered the sequence from the Red Grit series into the Upper Cretaceous limestone a perfectly conformable one.

The most complete section that I have seen lies in a small valley to the north of Ishpushta. Here, however, there appears to be an unconformity, although it may not represent any particular break in continuity of deposition. The uppermost beds of the Red Grit series are a red limestone overlain by a red pisolitic rock very like "low-level" laterite. This is overlain by a conglomerate followed by sandstone and gypsum, overlain in turn by limestone. There appears to be a slight discordance at the base of the conglomerate, which, together with the sandstone and gypsum, seems to belong to the overlying limestone. Often, however, these beds are absent and the limestone, which is usually a flaggy rock made up of comminuted fragments of shells, lies unconformably on everything below. There is thus, at the base of the limestone, a well-marked overlap, representing the great Cretaceous transgression which affected such a wide area in Central Asia and which is usually attributed to the cenomanian period (**28**, 290). Although fossils are fairly numerous in the beds above the basal limestone, I was unable to collect more than a very few and these are all rather badly preserved. In Upper Saighán some shaly marls and arenaceous limestones yielded echinoids and ammonites, which my colleagues, Messrs. E. Vredenburg and G. H. Tipper, have been kind enough to examine for me. I am indebted to Mr. Vredenburg for the following note on the echinoids :—

"The four specimens of a spatangoid echinoderm are too crushed and too incomplete for specific determination. Nevertheless the generic characters are perfectly recognisable; the specimens belong to the genus *Micraster*, the extremely short ambulacral petals recalling forms from the Cretaceous of Europe. So far as I am aware, this is the first Cretaceous *Micraster* obtained in Asia. None, at least, are known from India or Persia. The rocks containing them cannot be older than Middle Cretaceous, probably not older than cenomanian.

"The smaller of the 'regular' echinoids is a *Cyphosoma*, but cannot be specifically determined."

Mr. Tipper refers the ammonites to the genus *Hoplites*. A small fragment of *Scaphites* sp. and a brachiopod very closely allied to, if not identical with, *Terebratula semiglobosa* d'Orb., also occur at the same horizon. The limestone overlying these beds is full of lamellibranchs, among which the genus *Exogyra* is very common and led Mr. Griesbach to call the rock "Exogyra limestone." *Gryphæa vesicularis* Lam. occurs in this limestone at about 150 feet above the horizon of the ammonites; a little lower down, the same rock has also yielded hippurites and *Pecten* (*Neithea*) *quinquecostata* Sow. The limestones, therefore, are perhaps not older than senonian, whilst the underlying marls may be as old as cenomanian.

Tertiary System

In Saighán and Káhmard, the limestone with *Gryphæa vesicularis* is overlain by a fine-grained bluish-grey concretionary sandstone, which is locally replaced by either clunchy shale or pale-grey calcareous shale followed by gypsum; above this is another bed of grey shale sometimes containing small veins and nodules of sulphur. Above this again are grey, brown or red shales. After this there is usually a pronounced unconformity, above which are beds of bright red conglomerate.

I have followed Mr. Griesbach in classing the whole of this series as Tertiary, although the boundary assumed between it and the undoubtedly Cretaceous limestone is merely a lithological one and has not been fixed from palæontological data; throughout Saighán and Káhmard, the horizon marked at one point by a concretionary sandstone and at another by a clunchy shale is undoubtedly the natural line to take as the base of the series. It will probably be necessary eventually to give this system a local name, but as its characters are decidedly variable, it seems preferable to risk a certain amount of inaccuracy and continue to call it Tertiary provisionally rather than to saddle it with a name which subsequent work may prove to be unsuitable.

Both in Mádar and in Káhmard there is a distinct unconformity in the middle of this so-called Tertiary system. The beds above the unconformity are red conglomerates and pebbly sandstones very suggestive of the Gobi series, of which they may perhaps be a distant outlier. They lie more or less horizontally on the folded and eroded edges of the lower beds. There was evidently a considerable time interval between the deposition of the two series. This unconformity escaped Mr. Griesbach's attention, for he states that at Mádar (which he writes "Mathár") there is a perfectly conformable sequence from the beds overlying the Upper Cretaceous limestone into the red conglomerates, which he regards as pliocene. The lower beds are, according to him, eocene and miocene; I had no opportunity of examining them in detail and found only a few indeterminable fragments of (?) *Ostrea* sp. in the lowest bed. Mr. Griesbach's inference of the presence of miocene beds is based on fossils collected by himself in his "Cerithium clays"; the species of his *Cerithium*, however, was not determined and the assumed miocene age of the clays is, therefore, open to question. I should be inclined to doubt the existence of miocene beds in Mádar and Káhmard and to refer the beds below the unconformity to the eocene and, following Mr. Griesbach, those above to the pliocene; the unconformity, particularly at Mádar, is too pronounced for the beds below it to be so closely associated in time with the overlying conglomerate.

In Ghorband, between Siah-gird and Parsa, what was once a broad river-valley, carved out of the Ghorband limestone and the slates and quartzites of the Paghmán range, is now filled with a thick series of soft shales below, with shales, sandstones and conglomerates above. Here and there a thin layer of coal, usually only an inch or two in thickness, runs through the shale or sandstone for a short distance. These beds lie unconformably on the Ghorband limestone (Plate 8, fig. 1); they have been considerably disturbed, and small faults are innumerable; the dip is usually at a fairly high angle (30° and over) to east or south-east. Between Faragard and Siah-gird, the upper beds are overlain by the bright red Upper Tertiary conglomerate.

Here, perhaps, we have a miocene series which would fill in the gap represented by the unconformity at Mádar and in other parts of Káhmard.

In Káhmard, Saighán and Bámián there are large deposits of clay, pebbly sandstone and conglomerate, which are presumably of Siwalik age ; they are more argillaceous than the Siwaliks which occur in their typical facies of conglomerate and pepper-and-salt sandstone throughout the Kabul plain, at Khurd Kabul, Jagdallak, Gandamak, Daronta and, in fact, at intervals all over the area between Kabul and the Khyber. At Khurd Kabul the upper conglomerates are underlain by marl and carbonaceous clay, the latter containing a few poorly preserved plant remains and also fragments of a small *Planorbis.* Similar carbonaceous beds also occur to the east of the Lataband.[1]

The supposed Siwalik age of all these rocks is not supported by any definite palæontological evidence, and lithological resemblance is often a very misleading guide. They are undoubtedly old river-deposits, laid down in the wide valleys which were formed during a Middle Tertiary period of crust-movement, and in the absence of other evidence, it seems best to group them with the similar Indian deposits of Upper Tertiary (Siwalik) age. They have undergone a considerable amount of disturbance since their deposition. On either side of the gorge of the Kabul river above Gogomanda, they are seen capping the cliffs a thousand feet or more above the present river-bed, whilst in the neighbourhood of Jagdallak their dip is almost vertical where they abut against the older crystalline limestone and schist. Out in the more open plains, however, they are often quite horizontal and apparently undisturbed.

Pleistocene.

Much of the alluvium of Koh-i-Dáman, of the Kabul plain and of the valley of the Kabul river is no doubt of pleistocene age, but there is

[1] *Infra*, p. 45.

nothing to distinguish it from the recent deposits of similar composition.

In the Gandamak plain there are several small hills made up of piles of enormous blocks of crystalline limestone, quartzite, granite and igneous rocks all jumbled together. The limestone blocks are especially large — up to 10 feet or 12 feet in diameter; other blocks are smaller, but often three, four and five feet in diameter. Whence and how these blocks came here it is difficult to guess, but their size suggests ice as the transporting agency. I only saw them in the immediate neighbourbood of Gandamak and they appear to be quite local. Rocks like them occur *in situ* in the Siáh Koh, but if they were brought to Gandamak by ice, one would be more inclined to look for the parent mass in the Safed Koh to the south.

Beautifully striated pebbles are found throughout the sandy plain between Jalalabad and Baoli; these might easily be taken for glaciated pebbles were they not also pitted in the manner so characteristic of sand-sculpture; as they occur under desert conditions, I have no hesitation in attributing their sculpture to wind rather than to ice. The pebbles are derived from the Siwalik conglomerates and occur now among the recent plain deposits; they are only referred to here in view of the fact that their sculpture might be attributed to post-pliocene glaciation and the deposit in which they occur be thus erroneously regarded as pleistocene.

III.—DESCRIPTIVE.

The Kabul river-valley below Jalalabad.

From Jalalabad, until it plunges into the precipitous gorges below Lalpura, the Kabul river runs through an alluvial valley, usually broad and open but occasionally closed in by the approach of the hills on either side. Here and there small hillocks and ridges rise up through the alluvium. On either side of the valley huge talus fans from the Safed Koh on the south and from the ranges of Kunar and the Mohmand country on the north, slope down to the river. Throughout

this area the rocks consist of slate, limestone and calc-schist, evidently the products of metamorphism of a sedimentary series. No fossils have been found in them and they may be of almost any age.

Limestone continues practically all the way from Ali Masjid to Landi Kotal, where it is succeeded by a thick series of slates. At about 8 miles from Landi Kotal on the road to Dakka the slate series is interrupted by a fault which brings in some thick-bedded limestone; this, however, soon gives place again to slate which is apparently the prevailing rock in the hills all round Dakka.

From Dakka onwards the road runs first through slate, then on to alluvium interrupted here and there by older rocks. Beyond Básáwal it passes through a low hill-range of slate, calc-schist and limestone, all greatly crushed, contorted and metamorphosed. Thence a broad alluvial plain stretches up to and beyond the village of Chahárdeh (Chardih), to the east of which a low ridge of limestone runs towards the river to join the Koh-i-Bedaulat.

From Chahárdeh the Jalalabad road continues in a north-westerly direction through the plain for several miles, but, just beyond Lachipura, runs on to the right bank of the Kabul river and skirts cliffs of quartz-schist and sericite schist, the latter with well-marked slaty cleavage. Similar rocks continue as far as Giridi Kach, where they give place to serpentine, with dolerite and a small amount of phyllite. These form the northern end of a group of hills composed chiefly of basic igneous rocks. Thence an open plain, interrupted only by some small granite hillocks at Jalalabad, extends to the foot of the Siáh-Koh.

The Siah Koh and neighbouring valleys.

Between Jalalabad and Gandamak.

The main road from Jalalabad to Kabul runs *viá* Gandamak to Jagdallak. On the right is the Siáh Koh with its schists and limestones, and far away on the left the forest-clad slopes of the Safed Koh. The intervening depression is filled chiefly with "pepper-and-salt" sandstone and conglomerates, with occasional shaly bands, all presumably of

Siwalik age. These beds form an anticline, of which the northern limb has a comparatively steep dip, sometimes as much as 30°, whilst the southern is flatter.

5, Siwalik sandstones and conglomerates. 4, 3, Metamorphic limestone and slate. 1, Alluvium of the Surkh-ab. 2, Granite.

FIG. 4.

Diagrammatic section across the valley of the Surkh-ab between the Siáh Koh and the Safed Koh.

Surkhpul.

The road enters the Siwalik beds just below Fort Battye, and continues among them for a short distance beyond Gandamak. At the low pass between Gandamak and Surkhpul they are reduced to a narrow strip of sandstone and shale lying unconformably on limestone and granite belonging to the crystalline series of the Siáh Koh. To the west of the pass they expand again and cover all the older rocks, which, except in some small hills to the south of Surkhpul, appear only in the valleys. The Siwaliks also run high up the southern slopes of the Siáh Koh between Surkhpul and Jagdallak, and are found on the Jagdallak pass (6,200 feet) between these two places. At about two miles below the pass and at a short distance from Jagdallak, the beds are very highly inclined, being sometimes even vertical. This high inclination has been observed at several localities in the neighbourhood of Jagdallak and the Siáh Koh. The disturbance is always most marked where the beds abut against the hill-masses, and this points to comparatively recent movement in the direction of elevation of the hills.

Jagdallak.

To the east of Jagdallak the Siwaliks run up to the steep hills of the crystalline belt of the Ruby Mines. The limestone is here about ¾ mile wide, and is broken up

into an irregular group of steep hills, with small, usually waterless valleys.

Sarobi.

On the north, west and south, the whole valley is filled with the same sands, clays and conglomerates which extend past Sarobi to the Kabul river on the north and to the flanks of the Karkacha range in Tezín on the west: they also appear to extend up to the Lataband (**10**, 23).

Valley of the Kabul river below Sarobi.

From Jalalabad a second road to Saróbi runs for the most part along the right bank of the Kabul river. For the first few miles, as far as the Surkháb, it lies on alluvium, then rises over the eastern end of the Siáh Koh, where the Kabul river issues through the Daronta gorge. This is cut through porphyritic gneissose granite, of which the foliation planes strike E.N.E.-W.S.W. with a very high dip to N.N.E. From Daronta a broad valley, filled with Siwalik beds, extends along the northern flanks of the Siáh Koh to Kach-i-Mahomed Ali Khan. Nothing but soft sand-rock and conglomerate is seen *in situ* throughout the whole distance of about 20 miles, but the streams from the Siáh Koh bring down pebbles of granite and dark basic rocks, chiefly epidiorite and allied hornblendic types. The Siwaliks continue for about four miles beyond Kach-i-Mahomed Ali Khan, when they give place to steeply dipping clay slates, well-bedded and cleavable. These continue for about three miles, becoming gradually more and more schistose until they are found as metamorphosed schists in contact with granite. The latter rock is the typical Himalayan biotite-granite, with veins of schörl-granite; it forms the high ridges on either side of the Kabul river, and continues—interrupted only once by a belt, about 1½ miles in width, of slate and schist—to within 3 miles of Saróbi, where it is covered by the Siwaliks of the Jagdallak-Saróbi area.

The Lataband and the Kabul Plain.

From Saróbi to Kabul, there are three roads: a northerly one along the Kabul river through the gorge known as Tangi Gháru, a central

one over the Lataband and a southerly route over the Haft Kotal to Khurd Kabul. I have travelled only by the first route, but returned from Kabul along the third to Tangi Tarakki, a few miles east of Khurd Kabul, whilst Mr. Griesbach has already described the rocks seen along the road over the Lataband.

Tangi Gharu.

After leaving Saróbi, the road *viâ* Tangi Gháru rises over a flat-topped ridge of Siwalik beds which separates Saróbi from the Kabul river at Kach-i-Sher Khan. On the top of the ridge, inliers of grey limestone, weathering brown, crop out through the Siwaliks. The limestone exactly resembles the Megalodon limestone in the Para stage of Spiti, and is full of similar heart-shaped sections of lamellibranchs, some of which are as much as a foot in length, and probably represent *Dicerocardium*, whilst the smaller ones are *Megalodon*. The same limestone appears to continue to the west along the high ridge on the right side of the Kabul river. The road strikes the river-bank at the small village of Kach-i-Sher Khan, and just above this point the Siwalik beds end and give place to serpentine which extends for about two miles up the river. On the hill-sides above the right bank, light-grey limestone, much crushed and folded, is associated with the serpentine. Westwards these are capped on the hill-tops by cliffs, which must be 1,000 feet high, of Siwalik conglomerate; this gradually spreads down into the valley of the river, which widens out, and, at Gogomanda, is a wide basin full of Siwalik deposits. Just above Gogomanda, these disappear again, and the river rushes through a narrow gorge cut through steeply dipping beds of limestone and slate with great masses of intrusive serpentine. Similar rocks continue all the way to Ishpul Bábá. Above this, slate and schist, with serpentine and other igneous rocks, extend for some distance up the gorge, when they give place to gneiss and granite. Towards the head of the gorge, the gneiss and granite form the lower slopes, the hills being capped, about 2,000 feet above the river, by thick beds of limestone belonging to the Khingil series. Here and there beds of this rock have been brought down by faults and run in almost vertical bands across the river, but as a rule it is confined to the hill-tops.

From Pul-i-Charki to Kabul the road runs partly over Siwalik beds—current-bedded sandstone, conglomerate and clay—and partly over alluvium. To the north, the metamorphic rocks of the Kabul series crop out from below the younger deposits, but a ridge at about two miles to the south-west of Pul-i-Charkhi is apparently composed of limestone of the Khingil series, dipping at a high angle to the north-east.

The Lataband.

From Mr. Griesbach's description of the road over the Lataband (**10**, 23; **13**, 69), it would appear that the rocks met with are very similar to those of Tangi Gháru.

The Siwaliks cover the greater part of the surface to the east of the pass and I am indebted to the courtesy of Dr. W. Saise,[1] late Superintendent of the East Indian Railway Company's collieries in Bengal, for the information that patches of carbonaceous matter, like those noticed in the Upper Siwaliks of Khurd Kabul, occur near Bárikáb. At Seh Bábá there are large masses of serpentine associated with schist and limestone. The rock on the Lataband is limestone, evidently belonging to the Khingil series. It extends to within 5½ miles of Butkhák, where it is replaced by red Tertiary conglomerate resting on schist and gneiss. From Butkhák onwards the road passes chiefly over alluvium. Tertiary beds, however, form most of the hillocks between Bagrami and Kabul. At Siáh-sang, just beside the road, a small patch of the Kabul crystalline series crops out from below the younger rocks.

Tezin and Khurd Kabul.

Nothing is known of the geology of the country along the third route between Jagdallak and the Haft Kotal, but viewed from a distance the ranges of Tezín appear to be formed of limestone, which may either belong to the Khingil series or may be Cretaceous. West of the Haft Kotal, the open country as far as Khurd Kabul is covered almost entirely by younger Tertiary deposits. At Tangi Tarakki, about four miles to the east of Khurd Kabul, these deposits consist of soft shales, often carbonaceous, with creamy white marls and thick beds of conglomerate. All these appear

[1] The services of Dr. Saise were recently engaged by the Amir for the investigation of certain supposed coal seams on the Lataband and in the Ghorband valley.

to belong to the Upper Siwaliks. Near Tangi Tarakki, the Kabul road skirts the high hill shown on our maps as "Khurd Kabul" (11,143 feet). The base of this consists of gneiss, schist and intrusive basic igneous rocks, which dip at high angles to the south-west, and are overlain with marked unconformity by the limestones of the Khingil series. The intrusive igneous rocks are apparently confined to the crystalline series and have not been found to extend up into the overlying limestones. The road to Kabul *viâ* Butkhák skirts the southern and western sides of this hill, and affords a fine view of the striking unconformity. At the northern end of the gorge known as the Khurd Kabul pass, the crystalline rocks give place to Upper Tertiary beds, and at Butkhák the road joins the Lataband-Kabul track.

Koh-i-Daman and Ghorband.

The hills separating Kabul from the broad valley of Koh-i-Dáman consist of the gneisses and schists of the crystalline series. To the north of Kabul, the *chaman* is skirted on its further side by a ridge of the same series; where the road crosses the Paimunár Kotal, the rocks exposed are gneissose granite with pegmatite and dykes of basalt. These are found again in the hills to the north of Kala-i-Haji and along the range running from south to north along the eastern side of the Istálif valley, where they are associated with mica-schist. The western flanks of the same range are covered with soft sand and pebble-beds, which may represent the Siwaliks, but are softer and less coherent than the beds of that series in other localities.

Parwan and Jabl-us-Siráj.

At the northern end of the Koh-i-Dáman, the Paghmán range merges into the Hindu Kush, and the gneissose granite of the former becomes replaced by the limestone, hematite and graphitic slates of the Kálu and Hájigak series. Behind Jabl-us-Siráj, and to the north of the Sálang river, the hills are formed of hematite and a reddish, probably dolomitic, limestone. The hematite occurs partly as a bed of soft earthy material with masses of micaceous iron-ore. Behind the outer ridge harder masses of the hematite are found embedded in the limestone, which is quite crystalline and of

various colours, including white, grey and red. With it are associated quartzite and some slightly schistose slate. These rocks form the high hill—Takht-i-Marwán—behind Jabl-us-Siráj; on the top of this hill and on its northern and western flanks, the sedimentary beds are penetrated by bands of schörl-granite, which is no doubt accountable for the local metamorphism.

Ashawa and Kaoshan.

The mutual relationships of the hematite and limestone are here very obscure, the one sometimes replacing the other quite unexpectedly. This might perhaps be attributed to chemical replacement of the limestone by hematite, but I am more disposed to assign it to irregularity of outcrop consequent on the extraordinary contortion, probably combined with overthrusting, that the beds have undergone all through this part of the Hindu Kush. A good example of the prevalent type of folding is seen on a spur run-

Fig. 5.
Folds in the Kálu series near Jabl-us-Siráj.

ning down towards the plain between the Sálang and Ghorband rivers (see fig. 5). At Matak, at the mouth of the Ghorband valley, the rocks on either side of the gorge are at first dark grey gneiss with porphyritic felspar. The rock often has a curiously conglomeratic aspect, which may perhaps be due to the effects of pressure tending to produce an autoclastic conglomerate. Immediately above the gorge the gneiss is replaced by graphitic slate, thin-bedded limestone and quartzite. A little further back in the hills the hematite bed runs across from Asháwá to Parwán. The horizon is a most useful one, and can be traced up the left side of the Ghorband valley almost all the way to Siáh-gird. Throughout this part of the valley the lower slopes of the Hindu Kush are formed of the Hájigak series—as represented by the

hematite and associated limestone—overlain by limestone, often crystalline, quartzite, schist and slate. For some seven or eight miles up the Kaoshán valley opposite Burj-i-Gul Ján, nothing else is seen; I was unable to reach the crest of the range, but it is almost certainly composed of granite. The sedimentary rocks are highly metamorphosed and suggestive of the Archæan group; for a long time I doubted the accuracy of Mr. Griesbach's suggestion that they were as young as Palæozoic, but the subsequent discovery of the hematite bed and its associated fossiliferous limestone on the Hájigak Pass converted me to this view.

Siah-gird and Waghzar.

The Ghorband valley between Matak and Siah-gird appears to run approximately along an anticline, but it is difficult to correlate the beds of the Paghmán range on the right of the valley with those of the Hindu Kush. Perhaps the difficulty is due to the fact that the Paghmán rocks have been less highly metamorphosed, but it is possible that the Tertiary and Recent gravels that fill the valley-bottom hide a fault. A traverse up the valley which comes down from the south-east to join the Ghorband river on its right bank at Siáh-gird, discloses nothing but slate, quartzite and some black shale. Slate and quartzite are the prevailing rocks right up to the snows at the head of the valley. The dip is usually northerly but occasionally in the opposite direction. I have referred these beds to the Helmand series, but their true stratigraphical position is doubtful. On the opposite side of the valley, in the Waghzar ravine, a considerable thickness of dark slate and quartzite is overlain by black and brightly coloured shales followed by red limestone; above this is more slate with bands of red and grey limestone. The latter is sometimes almost entirely composed of crinoid stems, which, however, are crystalline and quite undeterminable. Slates, calc-schists and quartzites seem to extend from Waghzar up to the crest of the Hindu Kush, where they are penetrated and absorbed by the granite. Metamorphism is everywhere most pronounced, and, both in Waghzar and in the next valley to the west, the sedimentary beds are invaded by igneous rocks including

serpentine and quartz-porphyry, the latter probably genetically connected with the granite of the Hindu Kush.

Kimchak and the Chahardar Pass.

The section along the Kimchák or Deh-tang valley up to the Chahárdár pass is similar to that in the Waghzar valley; it has been described by Mr. Griesbach (**10**, 22) who refers to this part of the Hindu Kush as "a succession of anticlinal folds, traversed by igneous rocks." The metamorphism of the sedimentary rocks is of an advanced type, and they consist of endless alternations of slate, schist, quartzite, limestone and calc-schist. The thickness appears to be very great, but this appearance is almost certainly deceptive, and is due to repetition by folding. The structure of the southern slopes of the Hindu Kush in Ghorband is in fact probably an elaboration of the *motif* illustrated in fig. 5 (*supra*, p. 47). At the same time faulting is very pronounced, and has greatly complicated the structure.

Faranjal and Lolinj.

At a short distance above Siáh-gird the Ghorband limestone rises into a high ridge in the centre of the valley, and extends nearly to Lolinj on the one side and up to and beyond Faranjal on the other. Owing to the shortness of my stay in the neighbourhood, I was unable to determine the relationship of this series of limestone and slate to the other rock groups of the Hindu Kush. It has undergone an extraordinary amount of disturbance. It is traversed by numerous faults both at Faranjal and in the hills on the opposite side of the valley, great masses of it being often merely limestone breccia. In Parsa it appears to be below the Helmand series, but the real relations of the two groups may be the reverse of the apparent.

Faragard and Gaoparan.

On the southern side of the Ghorband valley, the limestone is overlain unconformably by the (? Tertiary) shales, sandstones and conglomerates of Yákhdara, Fáragard and Gáoparán (Plate 8, fig. 1). Similar deposits occur also on the left side of the valley, and cover a considerable area between the Dehtang stream and Faranjal; they are chiefly conglomerate, which

is often bright red, and pebbly sandstone, underlain by shale and sandstone. At Faranjal the Ghorband limestone is faulted and brecciated, and at about half a mile higher up the valley, there is a large mass of intrusive serpentine. Thence to the head of the valley, the limestone continues along the left side, whilst, on the right, it is to a great extent covered by Tertiary deposits. Immense masses of these fill the valley of the Turkoman dara in the neighbourhood of Lolinj, and extend over the hills on the east, lying unconformably on the slate and limestone series. They consist of clay, shale and conglomerate, and must be at least 2,000 feet thick; they have been considerably disturbed, and sometimes dip at angles of 30° and over, though the general effect is more or less flat.

The Shibar Pass.

At the head of the Ghorband valley, limestone extends over the southern slopes of the Hindu Kush and probably over part of the downs of the Shibar pass. In crossing the pass, I did not follow the road, but went up the Sangandao valley, for a few miles, then crossed the hills westwards and joined the road again near the western foot of the pass. Looking southward from the hills above the pass one sees a broad wind-gap filled apparently with soft Tertiary clays and conglomerates similar to those of Lolinj in the Turkoman dara. Behind these, again, is a high range of dark rocks, the continuation of the Koh-i-Bábá where it merges into the hills of Ghorband and the southern flanks of the Hindu Kush. The rocks also are probably the continuation of those of the Koh-i-Bábá, that is to say of the Kálu series, with the hematite bed on the crest of the range.

On the north of the Shibar pass, I noticed only limestone; the same rock runs westwards into the Shumbal valley, and the road to Shumbal caravansarai and thence to Balula passes through a magnificent gorge carved out of the steeply dipping—often vertical—beds of limestone (Plate 9). In the upper part of the gorge, just above the junction of the stream from the pass with the Shumbal river, the limestone cliffs are honeycombed with pot-holes, which are full of river pebbles but are many feet above the present stream level. Both in the stream-bed and on

the cliffs on either side of the valley, large blocks of a coarse conglomerate can be seen lying about up to three hundred feet above the present valley-bottom. The rock is quite indurated, and is composed of pebbles of gneiss, slate and quartzite. The blocks are so large that one would not expect them to have travelled far, yet I failed to find the rock *in situ* in the neighbourhood; the present stream is quite insignificant, and certainly could not have transported them, and ice suggests itself as the most probable agent of their distribution. It must be admitted that the blocks show none of the characteristic effects of glaciation, but the ridge behind the caravansarai at Shumbal is exactly like a moraine, and at a higher elevation one would not hesitate to regard it as such. The only undoubted moraines that I met with in this area were near the top of the Chahárdár pass (13,900 feet), whilst there were no traces of glaciation below 10,000 feet in the Dehtang valley, which is a typical **V**-shaped river-valley. When one remembers, however, that at the present day glaciers descend in North-Western Kashmir to about 8,000 feet, their existence in the Shumbal valley (about 9,000 feet) at no very distant date in the past does not seem impossible.

At Shumbal I found, for the first time, completely determinable fossils; the limestone mass on the south of the road, at the junction of the stream from the Shibar pass with the Shumbal river, contains *Fusulinidæ*, including *Fusulina uralica* Krotow. The limestone on the northern side of the pass is presumably the continuation of this belt. Among Mr. Griesbach's collections from Afghanistan I found three pieces of limestone $\left(\frac{H47}{712} \text{ and } \frac{H47}{713}\right)$ the locality of which was given as "1 mile west of Kala-i-Ali Madat, western slope of Shibar pass." I did not discover these specimens until after my return from Afghanistan, and I have not been able to identify Ali Madat's house from my notes. The only important house on the western slopes of the pass, however, is perhaps a little less than a mile to the east of the mouth of the Shumbal gorge, and the locality in question is probably on the belt of Fusulina limestone near Shumbal. The specimens are rather

puzzling, for only one of them is Fusulina limestone, whilst the other two are full of nummulites! I saw no trace of nummulitic limestone in this neighbourhood, but it is of course possible that it may occur to the south of the Shibar pass. This does not seem very probable, however, since such Tertiary beds as have been observed in Ghorband and Bámián are all shales, clays and conglomerates of estuarine or fluviatile original and probably much younger than nummulitic. Perhaps the association of the two different rocks under one number was due to accidental mixing of specimens.

Bamian.

Shumbal to Balula and Topchi.

From Shumbal the Fusulina limestone extends to within about a mile of Balula. It is rather massive above and thin-bedded below. It has been intensely folded (Plate 9), and its great apparent thickness is no doubt partly due to constant repetition. At the lower end of the gorge, the limestone contains *Schwagerina princeps* Ehr., *Neoschwagerina craticulifera* Schwager and *N.* (*Sumatrina*) *annæ* Volz. At about a mile above Balula, the valley opens out slightly, and the prevailing rock is crushed and faulted limestone with some slate. At and below Balula intrusive serpentine occurs in great quantity.

Beyond Balula the road to Bámián turns to the south, and, after passing through another deep gorge which traverses the Fusulina limestone, emerges at Kaoshandás on to a belt of shale and conglomerate. I took these rocks at first for a crushed and indurated facies of the Tertiary beds of Ghorband, but subsequent acquaintance with the Red Grit and plant-bearing series of Saighán has left little doubt in my mind that the Kaoshándás beds belong to these series and not to the Tertiary; unfortunately I had no opportunity of revisiting the area, and was unable to verify this. The conglomerate extends for a considerable distance and spreads over the Kashka pass; a very large percentage of the component pebbles are hematite, derived no doubt from the hematite bed which, towards the south, is not far off in the Koh-i-Bábá.

The same series continues into the valley of the Bámián river, and the conglomerates of the Red Grit series extend from Kala-i-Zohák, a picturesque ruin on the cliffs above the right bank, to Paimúri at the mouth of the Kálu gorge. It also extends up the right bank of the river for some miles, and is overlain on the northern slopes of the Koh-i-Bábá by the Upper Cretaceous limestone.

Below Tópchi an old brecciated limestone is found on the left bank of the river; it is more or less crystalline and apparently unfossiliferous; but is presumably part of the Fusulina limestone series. It is similar to the grey limestone of the gorge between Bámián and Ak Robát, and to the Ghorband limestone.

The Bamian valley above Topchi.

About 1½ mile above Topchi, the centre of the valley is occupied by a group of hills of grey carbonaceous shale (the Saighán series) overlain by the Red Grit series; this is associated with Cretaceous limestone, but all three series have been greatly disturbed, and are jumbled together in inextricable confusion. To the north of this locality, the hills on the left side of the valley contain lark limestones, occasionally containing *Fusulina*, infolded with and interfaulted among the Saighán and Red Grit series. The structure of this area is extraordinarily complicated, and might be compared to that of a gigantic fault-breccia. Similar conditions, due no doubt to overthrusts, prevail in parts of Ghorband and in lower Saighán.

The Koh-i-Baba.

The upper part of the Bámián valley is filled by soft fluviatile clays and argillaceous conglomerates, all of which are presumably of Upper Tertiary age (Pl. 10).[1] They lie almost horizontal, and extend up the flanks of the Koh-i-Bábá on the one side and of the Koh-i-Ghandak on the other. The main mass of the Koh-i-Bábá is formed of slate and quartzite—probably the continuation

[1] Mr. Griesbach states that these beds include members of the whole Tertiary system as developed in Káhmard and Afghan Turkistan. When he passed through Bámián, however, he was suffering from an attack of malaria and, being unable to examine the valley personally, was dependent for his information on the observations of fellow-travellers who were perhaps not expert geologists. I could find nothing resembling the eocene of Káhmard.

of the Kálu and Helmand series—with a certain amount of granite, which, however, is chiefly confined to the higher peaks. Between this backbone of old rocks and the Tertiary deposits on the flanks of the range, there is a strip of Mesozoic beds, consisting chiefly of Cretaceous limestone with here and there a patch of the Red Grit series cropping out from below. These are separated from the slates and quartzites by a fault which appears to run all along the northern side of the Koh-i-Bábá in Bámián. It has been met with behind Koh-girdak (6 miles S. S. W. of Taibut), again in the upper reaches of the Chapdara a little further to the east, and also on the northern side of the belt of gneiss at the mouth of the Paimúri gorge. It probably continues eastward to Irák and possibly across the Shibar pass into Ghorband. This, however, is only a suggestion, as we know nothing of the higher hills between Paimúri and Shumbal.

Khwajagar and Koh-i-Ghandak.

On the left side of the Bámián valley, the Tertiary beds cover the greater part of the southern flanks of the Koh-i-Ghandak on the north of Taibut. They are never very thick, probably not more than a few hundred feet, as the underlying rocks, on all of which they lie unconformably, frequently crop out more or less unexpectedly. A few miles above Taibut, the Cretaceous limestone appears to spread over the flanks of the hills all along the left side of the valley, and never to be very far below the surface. At about two miles to the north-east of Taibut, in the Khwájagar ravine, erosion has laid bare the underlying rocks which are chiefly hard dark limestone with a little slate. The limestone is like that in the gorge above Ziárat Chashma Shafan, between Bámián and Ak Robát, and is overlain by Fusulina limestone similar to that of the Shumbal-Balula section. The latter rock is well seen at about 4 miles above the mouth of the valley. *Fusulinæ* are very plentiful, and almost every boulder or pebble lying in the valley-bottom is full of them. A very conspicuous and common species is *F. elongata* Shumard, which is found at the point marked 1 on Plate 8, fig. 2. Above this is the brachiopod horizon (*supra*, p. 27) and some distance above

this again are high cliffs of massive light grey limestone full of *Neoschwagerina primigena* Hayden. I do not know what overlies these beds, as I was unable to visit the top of Koh-i-Ghandak, but they are probably covered unconformably by the Upper Cretaceous limestone, which spreads out towards the west and comes down into the Bámián

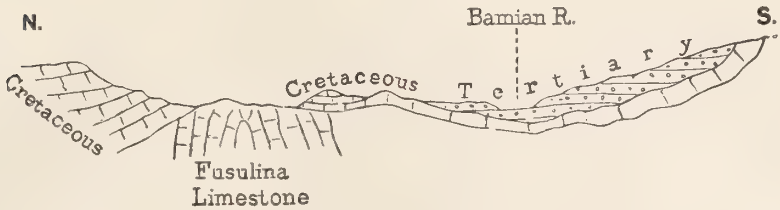


Fig. 6.

Probable section across the Bámián valley between Taibut and Ziárat Chashma Shafan.

valley at a few miles above Taibut. Above Ziárat Chashma Shafan, it overlaps dark slates which lie, apparently conformably, on the massive dark grey limestone of the gorge. In the gorge and at the upper end of it, it overlaps first the massive limestone and then the underlying slates and quartzites. At the foot of the ascent to Ak Robát Kotal the rocks underlying the Upper Cretaceous beds are chiefly dark limestone, which, higher up on the pass, contains crinoid stems and fragments of *Fusulina*. To the west of this, the principal rocks are members of a group of basic igneous intrusions, of which serpentine is the predominant type ; these continue far up the valley towards the Kotal-i-Chap Kolak and along the new road to Ak Robát.

Ak Robat.

The rocks of the gorge between the *ziárat*[1] and Ak Robát were described by Mr. Griesbach in some detail (**9**, 240). The lower end of the gorge is cut through a dark massive limestone in which he noticed indeterminable casts of brachiopods. He regarded the limestone as older than the quartzites, grits and slates which form the sides of the upper part of the gorge as far as the southern

[1] *Ziárat*, a Mahomedan shrine.

foot of the Ak Robát Kotal. The conditions here are rather obscure and all the rocks much disturbed, but the general dip between the Kotal and the massive limestone of the lower end of the gorge is south-easterly and I believe that the limestone overlies the grits and the quartzites. Taking the section in what I regard as ascending order and starting from the only horizon in which determinable fossils have been found, *viz.*, the Fusulina-bearing crinoid limestone of Ak Robát Kotal, we find this limestone, which is a dark schistose rock, cropping out on the descent from the top of the pass towards Bámián. Similar limestone occurs again lower down in the main valley at the foot of the pass and is overlain by a thick series of slate, quartzite and grit, much folded, but dipping in the main at high angles to the south-east. At the lower end of the gorge this is overlain by massive limestone through which the river rushes in a narrow channel between high vertical cliffs. The latter limestone is the rock in which Mr. Griesbach noticed remains of brachiopods. It is to a large extent crystalline and is penetrated by a network of fine veins of white calcite which has presumably been deposited along planes of fracture. Numerous small lenticular bodies scattered throughout the rock are very suggestive of *Fusulinæ*, but their structure has been so obscured by metamorphism that I have not been able to confirm this.

Ak Robat to Saraiak.

Between the top of the Ak Robát Kotal and the southern foot of the Kotal-i-Katár sum[1] I have no observations, but where the road to Saighán finally leaves the valley above the caravansarai, beds of crystalline limestone and slate, the former containing pebbles of quartz, flint and chert, dip to the south and overlie grit, conglomerate and quartzite which extend up to the top of the pass. All these have at first a southerly dip but the crest of the range is an anticline and on the northern slopes the beds dip away towards the valley of Saighán. I include the crystalline limestone just mentioned in the Fusulina Limestone series.

[1] This is the name employed on our maps. Mr. Griesbach refers to this pass as the northern Ak Robát.

Saighan and Kahmard.

The cap of Cretaceous limestone which apparently covers Koh-i-Ghandak does not extend as far westwards as the Kotal-i-Katár sum. Intrusive igneous rocks are plentiful and may belong to the group so largely developed in the valley below the village of Ak Robát. To the north of the pass the rocks are quartzite, slate, phyllite and graphitic slate and schist which I refer to the Helmand series. At a few miles below the pass a belt of granite interrupts the sedimentary sequence and extends to below Sokhta Chinár. Beyond this and not far from Saraiak, the sedimentary rocks re-appear and consist of quartzite and slate; they are followed by gneiss and serpentine, the former being perhaps a product of the metamorphism of the arenaceous members of the Helmand series by the basic intrusions. Conspicuous masses of crystalline limestone can be seen high up on the hills to the west of Sokhta Chinár; they include many varieties, some white and coarsely crystalline, others fine-grained saccharoid marble, either white or dark grey. I believe these to be the representatives of the Fusulina limestone series of Ak Robát, the advanced stage of alteration being due to the intrusive granite.

Below Sokhta Chinár the hills on the right side of the valley are capped by Cretaceous limestone and Tertiary conglomerate, lying in almost horizontal beds and with striking unconformity on the old slates (Plate 7). The slate series is presumably that termed by Mr. Griesbach the "anthracite group" of Saighán and regarded by him as Permo-Triassic. I have referred it to the Helmand series which I class tentatively as Carboniferous. Mr. Griesbach regarded it as younger than the massive limestone of the gorge below Ak Robát, and consequently referred it to the Permian and Lower Trias. His interpretation of the section between Bámián and Saighán is in fact exactly the reverse of mine. His observations were made under very trying circumstances (see footnote to page 53) to which must be attributed his impression that the beds on the south of the Ak Robát Kotal were dipping steadily to the north-west. If such were the dip, the relative

stratigraphical positions of the Fusulina limestone and his "anthracite group" would undoubtedly be such as he assumes, but I passed through the gorge twice and examined the section carefully in this respect. The prevailing dip is certainly south-easterly, and unless there is either inversion or overthrust, of which I have no evidence, the limestone of the lower end of the gorge must be younger than the slates and quartzites which underlie it. The graphitic character of the series is very conspicuous on the right side of the Saighán valley just above Saraiak, where the rock is a graphitic schist. I found nothing, however, that seemed to suggest anthracite or other combustible material.

Upper Saighan.

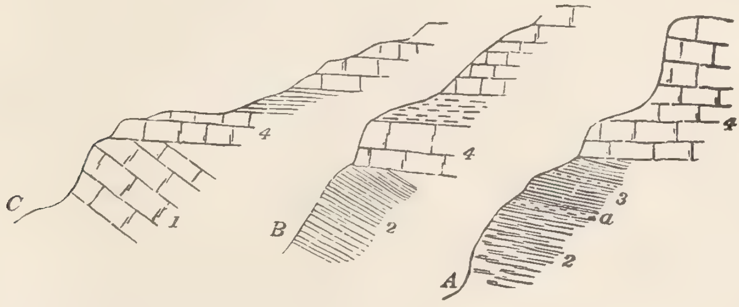
At Saraiak, the Cretaceous beds come down into, and spread across, the valley, and abut against the shales of the Saighán series; the junction is a thrust-plane connected with a recumbent fold which runs all along the northern side of the valley (see Plates 5 and 11). Above Saraiak the valley

FIG. 7.
Section across Saighán valley, near Deh Imám.

opens out into a wide basin, and is filled with Upper Tertiary deposits which lie unconformably against the Cretaceous limestone and Saighán series on the left, and on the right spread far up on to the hills above Sokhta Chinár. At about a mile below Deh Imám and on the same side of the river, the Cretaceous beds dip steeply down into the valley, and are overlain unconformably by a mass of horizontal Tertiary deposits lying in a bay in the eroded Cretaceous outcrop. The Tertiary beds are much thicker here than in Bámián, their total thickness being probably 2,000 feet at least. They consist chiefly

of conglomerate underlain by a curious calcareous rock resembling travertine, which latter is found on the southern side of the Kotal-i-Kabúchi and for some miles up the valley of Sayad Bábá. In the latter locality it occurs in thick masses associated with conglomerates and pebble-beds. It appears to be a purely local development of the Upper Tertiary sub-aërial facies. Just below the junction of the valleys of the Ao dara and Begal, these beds overlie bright red conglomerate which is presumably the equivalent of the red Upper Tertiary conglomerates of Banák and Mádar in Káhmard (*infra*, p. 67). In Sayad Bábá the junction between the Tertiary and older rocks is a fault which runs from E. by N. to W. by S. Beyond this fault, the hills on the left side of the valleys of Begal and Sayad Bábá are composed of dark slates with ash-beds and volcanic breccias capped by Cretaceous limestone. The lower beds are evidently the Doáb series; they are very variable in thickness, being as much as 1,000 feet thick in Begal opposite the mouth of the Ao dara, but much thinner in the neighbourhood of Khárgin dara. In the latter locality and on the hills between Begal and Dara Hech, the Saighán series appears between the Doáb volcanics and the Cretaceous limestone; it is thickest on the east,

Sayad Baba.



4, Cretaceous limestone. *2,* Doáb series.
3, Saighán series. *1,* (?) Fusulina limestone.
a, white basal bed of Saighán series.

Fig. 8.

Sections on the left side of Khargin valley; *A,* ½ mile above the mouth; *B,* 1½ mile above the mouth; *C,* 2 miles above the mouth.

rapidly thinning out westwards and southwards and dying out altogether in Khárgin dara at about two miles above the junction of this valley with Begal (Plate 12). Figure 8 shows the conditions prevailing at different points in that valley. It will be seen that the Doáb series, like the Saighán series, also thins out, and is completely overlapped by the Cretaceous limestone.

Begal and Khargin.

In the Begal valley, at about a mile above the mouth of Khárgin dara, a conglomerate occurs some little way up in the Doáb series and extends into Khárgin dara; its thickness is very variable, sometimes dwindling from fifteen or twenty feet to a few inches. Possibly it is an old river conglomerate. In Khárgin dara it overlaps the lower beds of the Doáb series and lies on a massive grey saccharoid limestone occurring in thick beds and resembling the limestone associated with the slate and graphitic schist series in the hills between Saighán and Bámián; both are like the limestones of Ak Robát and Ghorband, with which I have classed them. A little way up Khárgin dara, the conglomerate is composed of rounded and angular blocks of all sizes from small pebbles up to masses, two feet long, of the underlying limestone. Except where the conglomerate lies immediately on the limestone, the latter rock has not been observed among the pebbles, which consist chiefly of quartz and various siliceous rocks, and are usually about the size of a hen's egg.

In Khárgin dara and Begal, there are thus two distinct overlaps, one by the conglomerate of the Doáb series and the other by the Upper Cretaceous limestone (Plate 13). Each of these oversteps all older beds down to the grey limestone. On the other hand, there is no trace here of the unconformity noticed in lower Saighán between the Saighán beds and the Doáb series, the passage from the dark shaly beds of the latter into the white sandstone and shale at the base of the former being seemingly perfectly normal. This section certainly suggests the association in time of the Doáb series with the Saighán series rather than with the Fusulina limestone and therefore offers important evidence against the correlation of the volcanics of Saighán with those of Darwáz.

In Ao dara the Doáb series consists of volcanic ash, breccia and beds of trap. It is overlain to the north by the Upper Cretaceous limestone, and to the south is replaced by the grey saccharoid limestone, which is locally seamed with black basaltic dykes.

Lower Saighan.

Turning now to lower Saighán, the rocks in the valley below Saraiak are greatly disturbed. On the left side of the valley at Delchi, the plant-bearing series is very conspicuous (Plate 11). It consists of dark shales with many well preserved fossil plants and some insignificant coal-seams. The lowest bed seen here is Cretaceous limestone dipping under the Saighan series along the overthrust already referred to (*supra*, p. 58). At a short distance below Delchi a bed of conglomerate belonging to the Doáb series occupies the centre of the valley and, being harder than the neighbouring rocks, has retarded the erosive action of the river; the result has been the formation of a narrow gorge with precipitous sides. On the right side of this gorge, the old slate and schist series is overlain unconformably by the Doáb conglomerate and this again on both sides of the gorge is capped, also unconformably, by the Upper Cretaceous limestone (see Plate 14). On the hills on the right side of the valley, the Cretaceous limestone is covered by horizontal beds of conglomerate, presumably of Upper Tertiary age.

Below the Delchi gorge, the valley rapidly widens again. It has been eroded out of the soft shales of the plant-bearing series which is very conspicuous below Khwajaganj, on the slopes below the Kotal-i-nálifarsh. Here the river takes a sudden turn to the right and again cuts its way through the conglomerate and shale of the Doáb series, which is replaced, below Baiáni, by schist and gneiss, presumably the easterly extension of the graphitic series of Saraiak. At Bágh-i-Haibak there is an extensive development of the volcanic beds of the Doáb series which is probably continuous along the gorge of the river down to Doáb-i-Mekhzarín.

The valley of the Surkháb below Doáb is clearly the structural continuation of lower Saighán, and the same rock-series continue

north-eastwards under the Kotal-i-Kálich and on towards Barfak, Tálá and the valley of the Andaráb. The chief difference between the stratigraphical sequence in Saighán and that found in the more easterly area is the thinning out and disappearance of the Red Grit series in Saighán. In the valley of the Káhmard river, between Dasht-i-Safed and Doáb, and eastwards as far as Tálá, this series is between one and two thousand feet thick. To the west of the Kotal-i-Kálich, however, it gradually begins to thin out, and on the hillsides above Khwájaganj, it disappears altogether, the Cretaceous limestone overlapping on to the Saighán series.

Doab-i-Mekhzarin.

Throughout lower Saighán the junction of the Doáb and Saighán series is obscured by horizontal deposits of Upper Tertiary age. On the right side of the valley of the Káhmard river, however, just opposite the village of Doáb-i-Mekhzarín, dark sandstones and shales of the Doáb series are found dipping to the south and forming a low arch on the left bank of the Saighán river (Ab-i-Saighán); on the north they are overlain by the Saighán series; the nature of the junction was not clear, and it may have been a faulted rather than an unconformable one. On the opposite side of the river, at Doáb village, the dark sandstones and shales dip to the north, and are overlain by trap, dykes of which cut across the sedimentary beds. Here the junction with the overlying Saighán series appears to be a conformable one; this appearance, however, seems to be due merely to approximate identity of dip in the two series, and evidence gathered further eastwards between Doáb and Ishpushta points to the presence of an unconformity, although the Khárgin section already described (*supra*, p. 60) indicates that this is not of great importance.

On the right bank of the Saighán river, a short distance above its junction with the Káhmard stream, the Doáb series appears to lie unconformably on massive limestone which occurs in considerable thickness along the southern side of the river. Unfortunately, the bridge over the Surkháb had been swept away and the river was impassable.

I was therefore unable to examine what may be an important section. In the distance the limestone resembled that of Khárgin, and perhaps the section here is analogous ; but it is on these slopes that one would expect to discover the true relationship between the Doáb series and the fossiliferous beds of the Fusulina limestone. Below Doáb-i-Mekhzarín, the Doáb series, with much volcanic material, extends along both sides of the Surkháb to Barfak. To the north the long slope up to the Cretaceous scarp is composed of the plant-bearing and Red Grit series (Plates 5 and 15). A good section of the whole group of beds, from Doáb series to Cretaceous, is found in the small valley of Ishpushta (fig. 9). Here dark needle shales, with some arenaceous layers, are

FIG. 9.

Section near Ishpushta in hills N.W. of Kotal-i-Kháki.

overlain by beds of grey volcanic ash. Over these is the Saighán series, at the base of which there is a bed of soft white rock almost a sandstone, but containing a considerable amount of volcanic material; it is probably an ash deposited in water. This is succeeded by the characteristic shales, sandstones and conglomerates of the Saighán series.

Amongst the shales of the Doáb series there are beds of amygdaloidal trap and numerous dykes ; the latter extend up into the basal

beds of the Saighán series which have been locally altered to slate and limestone, thus proving that volcanic activity persisted into the Jurassic period.

Ishpushta.

The Saighán series passes up through conglomerate into the Red Grit series. At the gorge at the head of the Ishpushta valley the following section is found (in descending order) :—

7. Upper Cretaceous limestone.
6. Sandstone with beds of gypsum.
5. Conglomerate.
4. Red pisolitic bed, like laterite.
3. Hard red limestone with *Rudistæ*.
2. Red sandstone.
1. Red conglomerate.

The lowest of these beds is the typical conglomerate, of which the greater part of the Red Grit series is composed ; beds 2 to 4 are the upper part of the same series and indicate merely slight modification in the conditions of deposition. Bed 5, however, inaugurates a complete change ; the remarkable red colour disappears and the conglomerate and overlying sandstone and gypsum belong to the Upper Cretaceous limestone (7) rather than to the underlying red beds. There appears to be a slight but distinct unconformity at the base of the conglomerate (5). At the same time the presence of *Rudistæ* confirms the views already expressed as to the Cretaceous age of the Red Grit series.

Barfak and Tala.

To the east of Ishpushta, the Saighán series continues over the Kotal-i-Kháki towards Barfak, eventually disappearing under the recent talus fans which cover the valley-bottom (Plates 15 and 16). The lower beds have been altered by dykes from the underlying volcanic series. Below Barfak on the way to Tálá the same conditions have been noticed among the small hills through which the road passes. Tálá was the easterly limit of my

tour, but the Saighán series and overlying Red Grits and Cretaceous beds seem to persist for a long way down the valley and probably run through Doshi and Khinján into Andaráb. The Red Grit series forms a conspicuous hill on the left side of the river opposite Barfak. The beds of red conglomerate have been cut into vertical cliffs, which, owing to the peculiar character of the jointing of the rock, might easily be mistaken at a little distance for beds of columnar basalt (see Plate 16).

The lower hills behind (south of) Barfak are formed of the Doáb series which here consists of dark needle-shales, sandstone and great masses of volcanic ash. The ash, which is grey on fresh fracture but weathers white, forms thick beds between the shales. On the left side of the small stream to the south of the village, there is a prominent peak, which, when viewed from a short distance away appears to consist of granite but is in reality composed of volcanic ash, in which are embedded blocks of all sizes up to six inches in diameter; these appear to be lapilli and are sometimes almost spherical, sometimes angular. The bed in which they occur is about 200 feet thick, but this thickness appears to be only local. In the hills between the river and the path to Ishpushta, there is a good exposure of the junction between the Doáb and Saighán series. The base of the latter is the usual white sandy ash; below this is grey ash underlain by dark needle-shale like a normal shale of marine origin. This part of the series contains bands of amygdaloidal trap, but is also thickly penetrated by dykes of dark grey trap and a fine-grained white felsitic rock which extend up into the lower beds of the Saighán series. For convenience the white sandy ash has been adopted as the basal bed of the Saighán series which is remarkable for the bright colours of its component rocks, whereas all the beds below the white ash are almost invariably dark.

Dasht-i-Safed.

Above Doáb-i-Mekhzarín, the valley of the Káhmard river is wide where it passes through the soft beds of the Saighán and Red Grit series, but at Tangi Muyak the stream has cut a narrow gorge across the steeply dipping

beds of Cretaceous limestone. Above the gorge, the valley on either side of Dasht-i-Safed is filled with Tertiary beds which overlie the Cretaceous limestone conformably on the south, but on the north have been over-ridden by older beds along a thrust-plane which runs across the valley and through the Dasht-i-Gazak into Begal in Upper Saighán. Above Dasht-i-Safed the rocks met with belong at first to the Red Grit series, but at a short distance above Andao, there is another deep gorge through the Cretaceous limestone. Here the Káhmard river turns at right angles to its former course, and after running from Saripul to Bajgáh along a synclinal trough in the Cretaceous limestone, suddenly swings round and cuts its way out across the southern limb of the fold. At the lower end of the gorge, the limestone is full of fossils ; a red arenaceous bed is particularly prolific and contains *Hippurites*, *Gryphæa*, *Exogyra*, *Pecten*, *Neithea*, *Turritella* and many other lamellibranchs and gastropods. *Cyclolites* sp. also occurs. No doubt this is Mr. Griesbach's 'Exogyra limestone.' Just above the gorge the prolongation of the Káhmard trough contains an assemblage of beds similar to those above the Cretaceous limestone near Dasht-i-Safed. The flaggy calcareous shales are the same and here also are associated with gypsum aud sulphur, but the latter occur in very much smaller quantities.

Kahmard.

Káhmard proper is a long narrow valley lying along a fold in the Cretaceous limestone: the northern side of the valley is formed by a recumbent anticlinal arch from the crest of which the younger beds have been removed, allowing the underlying Red Grit series to crop out here and there. The southern side is a great bare wall of rock many hundreds of feet high and sloping at an angle of about 40° from the edge of the Dasht-i-Gazak down to the river-bank ; so closely does the valley follow the axis of the fold that for long distances the surface of this wall is a single bed of the Cretaceous limestone. Plate 17 is a photograph of Bajgáh gorge (Tangi Bajgáh) from the north. Through the gorge is seen the sloping surface of the Cretaceous limestone which forms the southern wall

of the valley; the Káhmard river flows between it and the gorge (fig. 10).

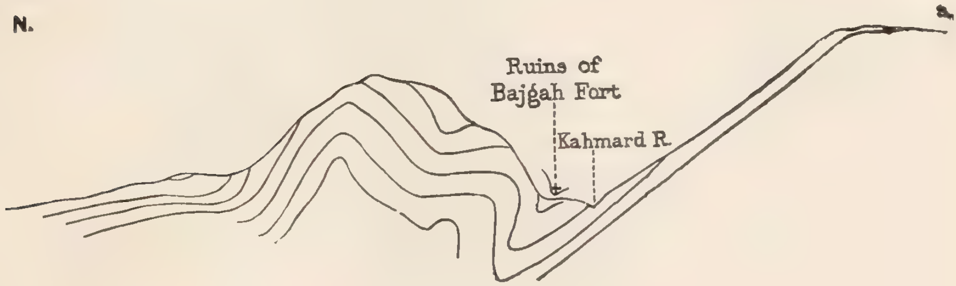


FIG. 10.

Section through the Bajgáh anticline and Káhmard valley, near Bajgáh.

At the upper end of the Káhmard valley, there is a wide amphitheatre in the Cretaceous rocks filled with brilliantly coloured beds—white, blue and red—representing the Tertiary system. On the right side of the river at Banák, concretionary sandy clays with thin layers of gypsum are overlain by limestone similar to that which contains sulphur at Dasht-i-Safed. Over this are bright red conglomerate and sandstone, lying unconformably on the older beds. The unconformity is well seen at the base of the Kotal-i-Dandán Shikán, where the red conglomerate lies with marked discordance on concretionary blue sandy clay which is adopted as the basal bed of the eocene.

Hajar.

To the north-west of Káhmard lies Hájar, a narrow valley closed at either end by a magnificent gorge cut through the Cretaceous limestone. The centre of the valley lies on the crest of an anticline, the oldest beds exposed being the upper part of the Saighán series (fig. 11); the sides of the valley

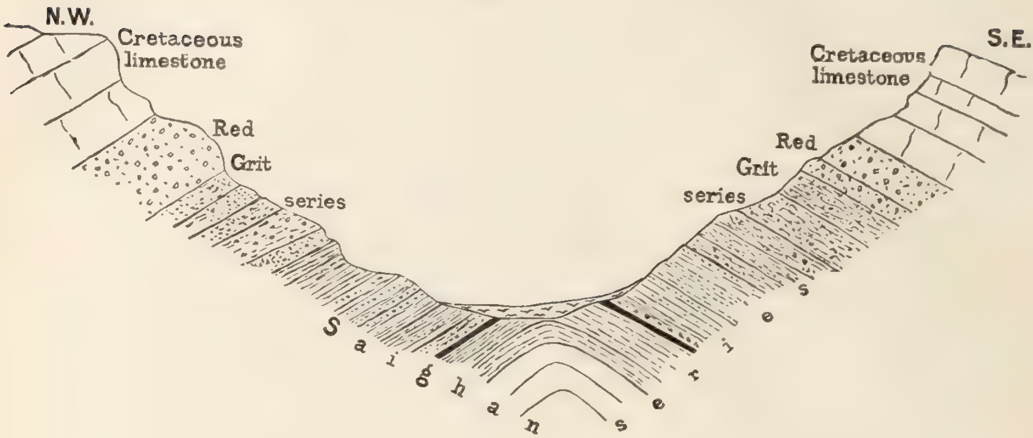


FIG. 11.

Section through the Hájar valley.

are formed of the Red Grit series capped by the Cretaceous limestone (Plate 18).

Bajgah and Madar.

As already pointed out, the lower end of the Káhmard valley where the river turns sharply to the south, is also filled with Tertiary beds similar to those of Dasht-i-Safed and Banák. About two miles above the bend is the ruined fort of Bajgáh[1] and here a deep and narrow gorge through the anticlinal arch of Cretaceous limestone connects the Káhmard valley with Mádar. Plate 17 is reproduced from a photograph of the gorge taken from the Mádar side and looking into Káhmard; figures 10 and 12 show the

[1] Mr. Griesbach's reference (**9,** 256) to Captain Hay's discovery of eocene fossils at Bajgáh was written when in camp and when he was unable to consult the original paper (**14,** 1126), which merely contains a few sketches made by Captain Hay of fossils that he had collected at and near Bajgáh. The sketches are too incomplete to be relied on for more than an approximate generic determination of the fossils, the majority of which I should be more inclined to think were derived from the Upper Cretaceous beds in the neighbourhood of Bajgáh Fort.

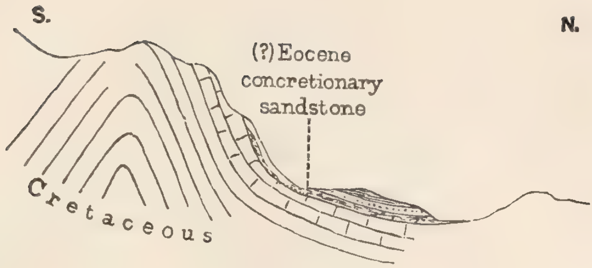


FIG. 12.

Section through Tangi Bajgáh and southern part of Mádar basin.

structure of the intervening ridge. The Mádar valley appears to be a true basin, filled with Tertiary beds which dip inwards on all sides and overlie the surrounding Cretaceous limestone conformably. Where the road issues from the northern end of the Bajgáh gorge, it passes on to the Tertiary beds and runs over these all the way to Mádar. In the centre of the valley, at a short distance to the north of the road, there is a well-marked unconformity, and the red Upper Tertiary conglomerate lies on the eroded edges of the folded Lower Tertiary beds. Along the northern side of the Tertiary basin, the beds are well exposed in a number of small ridges. The Upper Cretaceous limestone is overlain by a fine-grained bluish-grey sandstone with pronounced concretionary structure. It is about 50 feet thick, and contains *Ostrea* sp. collected into little groups. It is overlain by pale bluish-grey shale, weathering almost white and passing up into sandstone and shale; in appearance the bluish-grey shale resembles the calcareous paper shales or marls of Dasht-i-Safed, but is not calcareous, and contains no sulphur. There is a considerable thickness of this shale which is overlain by red sandstone with bands of shale containing thin layers of gypsum. This is followed first by red shale and clay, and then—unconformably—by the Upper Tertiary red conglomerate. Throughout this area there is a marked contrast between the degree of folding of the beds referred, respectively, to the Lower and Upper Tertiary. The former have shared

in all the disturbances to which the underlying Cretaceous rocks have been subjected, whereas the red conglomerate and overlying beds are comparatively little disturbed. For this reason I consider that the inter-Tertiary unconformity represents a very considerable time-interval.

Kara Koh.

At the north-eastern corner of the Mádar basin, the road to Haibak leaves the Tertiary beds and, skirting a magnificent dome in the Cretaceous limestone (Plate 19), ascends, first, through a narrow gorge in the same rock; subsequently it passes over some small outliers of the Lower Tertiary beds, to the Kárá Kotal, where there is a large outcrop of dark green diabase. The field relations of this rock were not ascertained, but it is probably intrusive among the Cretaceous beds. From the Kárá Kotal the Upper Cretaceous limestone extends westwards forming the high snowy ridge which separates Mádar and Hájar from Ao-Khorak. On the north, the Red Grit series is exposed along the flanks of this ridge, and extends down into the Khorak valley, where it is underlain by the Saighán series. The latter is well exposed along the banks of the stream, and the characteristic fossil plants occur in some profusion in shales on the left bank about half a mile below the small village of Khorak-i-paián. The hills on the northern side are capped by Cretaceous limestone, which lies unconformably on the Saighán series, and descends here and there into the valley; the structural conditions are rather complicated, and suggest the presence of an overthrust.

The Saighán series extends to the top of the Kotal-i-Sabz (*vulg.* Kotal-i-Saozak) and down the other side into Chahil, where it is overlain by Cretaceous limestone and underlain, presumably, by the beds with *Halobia* sp. (*supra*, p. 31). The Kotal-i-Sabz was the limit of my tour, and I was unfortunately unable to visit either Chahil or Dara Yusuf. From Mr. Griesbach's description of the latter area, however, it would appear that the sequence in this part of Turkistan is different to that in Saighán, the volcanic element of the Doáb series being apparently absent to the north of the Kárá Kotal. The base of the Saighán series is not exposed in Ao-Khorak.

The Upper Helmand and Kabul Valleys.

Palmuri and Kalu.

Reference has already been made to the rocks seen in the mountains between Bámián and the Helmand (*supra*, pp. 23, 25, 54). The Kálu river, rising behind the village of the same name, in the snow-capped granite peaks of the Koh-i-Bábá, cuts its way across almost the whole width of the range, and issuing through a gorge second in grandeur only to Tangi Gháru, joins the Bámián river at Kala-i-Zohák. For the last two miles of its course it runs through the conglomerates and sandstones of the Red Grit series. Where it issues from the gorge at Paimúri, it passes under two natural bridges of travertine deposited from the saline springs which rise along the Koh-i-Bábá fault (*supra*, p. 54; see also **20**, 531). The gorge itself is carved through the Kálu series of gneiss, quartzite and slate; it is about a mile and a half in length, and at the upper end was formerly blocked by a landslip, which has resulted in the checking of the current above and the consequent formation of a wide valley of erosion the bottom of which is filled with river deposits, through which the river meanders. Above this 'chaman' and at about two miles below Kálu, the conglomerates already mentioned (*supra*, p. 23) are seen along the road and are between 200 and 300 feet thick. The graphitic schists are seen in the hills on the right side of the river, opposite Kálu caravansarai. The valley here is strewn with blocks of hematite of all sizes, which have been derived partly from the high ridge to the north-east, and partly from small ridges and outcrops a few hundred yards away to the south-east and south. On the way up to the Kotal-i-Hájigak, the fossiliferous limestone crops out

Kotal-i-Hajigak.

at the foot of the pass on the left side of the road, where the latter meets a stream flowing down from the north. It appears to be overlain by the Helmand series of slate and quartzite. All the beds dip more or less steadily to the south, but the structure is complicated by numerous subsidiary folds. Limestone crops out again on the north side of the pass near the top and appears to dip to the north but lower down on the west side the southerly dip is quite clear.

On the east of the Kotal-i-Hájigak down to Kharzar, the prevailing rock is slate. At Kharzar this is replaced by a great thickness of quartzite, which has the shining black surface so commonly found on arenaceous rocks weathering under desert conditions; it exactly resembles hematite, and at first sight one is inclined to refer all the tall black masses of rock standing out so conspicuously in the Helmand valley to this mineral; but I examined a large number of outcrops and in not a single case did those east of the Kotal-i-Hájigak prove to be iron-ore.

Kharzar and Siah-sang.

From Kharzar to Siáh-sang there is a monotonous repetition of the same rocks—quartzite and slate—all the way. For some miles below Siáh-sang the conditions continue much the same, but towards the Helmand signs of contact-metamorphism begin to be apparent; the slates become silky at first, then are phyllites, and subsequently contain considerable quantities of chiastolite. Near the river they are associated with grey schistose limestone and calc-schist, and on the east of the river between Gardan Diwál and Jaokul, the series has become definitely a highly metamorphic one composed of schist and crystalline limestone. The limestone is very conspicuous, and forms a belt nearly 1,000 feet broad. It is a grey saccharoid rock with *augen* of quartz and calcite, which may, perhaps, be the remains of fossils; some of the fragments of quartz, however, are very like included pebbles. Part of this limestone belt consists of white marble with graphite. The metamorphism is due to biotite-granite which occurs in some quantity to the south of Jaokul.

The Helmand at Gardan Diwal.

Between Siáh-sang and the Helmand, the prevailing dip is southerly, but northerly dips have also been noticed over considerable distances, and it is evident that the whole series has been repeatedly folded. To the south of Gardan Diwál, on the right bank of the river, and again in the valley of the stream which passes in front of the Jaokul caravansarai, the slates are chiefly vertical.

To the south-east of Jaokul, similar rocks extend to the Kotal-i-Unai, which lies on the divide between the Kabul and Helmand river

basins. A dark greenish conglomerate, very compact and fairly coarse, occurs in large quantity to the west of the *col*; I did not see it *in situ*, but it evidently belongs to the slate series in this locality, and suggests correlation with that below Kálu.

The valley of the Kabul river.

In the valley of the Kabul river the rocks consist at first of schistose slates, rapidly giving place to gneiss, schist and crystalline limestone; the last-named rock forms a thick bed extending from Dahán-i-Unai along the left side of the valley down to Sar-i-Chashma. Lower down the valley slates re-appear, but white beds seen high up on the mountain sides probably represent the crystalline limestone.

What relationship there is between the comparatively little altered slates and quartzites of the Hájigak Kotal and the schists and other highly metamorphosed rocks of the Helmand and Kabul rivers, it is impossible to say. The latter may be merely the altered representatives of the former, but there is no evidence of this, and, judging from the great area covered by these metamorphic rocks, which extend from the Helmand to Kabul, it seems quite likely that they may include metamorphosed representatives not only of the Hájigak beds but also of the older sedimentary systems. The conglomerates of the Kotal-i-Unai suggest correlation with those of Ak Robát, whilst the gneisses, schists and crystalline limestones may correspond with those of the valley between Ak Robát and Saraiak in Saighán, and possibly also with those of the Kabul river to the east of Sarobi (p. 43).

IV.—GEOLOGICAL HISTORY OF AFGHANISTAN.

The geological history of Afghanistan, like the political, is one of instability. Four well-marked unconformities have been recognised. The first occurs between the Khingil series of Khurd Kabul hill and the crystalline limestone and schists of Kabul. It is impossible to estimate the lapse of time represented by this break, since the age of the crystalline rocks has not been determined. It is clear, however, that they were folded and metamorphosed before the deposition of the Khingil limestone since the rocks intrusive in them do not extend up

into the overlying beds. At the same time the axes of their folds in the Khurd Kabul hill are almost at right angles to those of the younger beds and it is evident that they represent an old, probably pre-Carboniferous land-surface.

The Khingil series is peculiar to this one area so far as we know. It is apparently different to the Upper Palæozoic facies of Bámián and the Hindu Kush, but related both to the Productus Limestone of the Salt Range and to the Trias of the Himalaya. Between Kabul and the Salt Range, the Productus Limestone has been found in the Bazár valley on the northern flanks of the Safed Koh (**15**, 111) and the same formation almost certainly forms part of the main range between the Bára valley and the Khyber. The presence of the Khingil series to the north of Tangi Gháru has been referred to above (page 44), but nothing is known of its extension beyond the range bordering the Kabul plain and even this has not been visited. The unconformity at the base of the series between Butkhák and Khurd Kabul inevitably suggests a comparison with the Aryo-Dravidian (Upper Palæozoic) unconformity of the Himalaya and one is tempted to see in these limestones proof of the extension as far as Kabul of the transgression characteristic of the Carboniferous Indian marine province.

At a comparatively short distance away, to the west and north-west of Kabul, the older sedimentary series are developed in a different facies, and in the Koh-i-Bábá and Hindu Kush we find evidence of the existence of marine conditions at least as early as the Devonian period and probably much earlier. The Kálu series, Hájigak limestone and the Helmand series represent, no doubt imperfectly, the Dravidian group of the Himalaya and indicate shallow-water marine conditions extending throughout almost the whole period of their deposition. The hematite bed and the graphitic slate suggest a temporary interruption and the prevalence of terrestrial conditions towards the end of the Silurian or beginning of the Devonian period. This was followed by re-submergence, and the formation of a coral limestone probably at no great distance from a coast-line, for the (?) subsequently-formed slates and

quartzites of the Helmand series bear witness to the proximity of a land-surface undergoing denudation. On the whole the conditions during the Dravidian era in the area represented by the Hindu Kush and Koh-i-Bábá were not unlike those prevailing at the time in the Tibetan zone of the Himalaya and the same sea probably covered both areas. This latter suggestion, however, must remain to a great extent hypothetical until fossils have been found in the Kálu series. The small fauna from the Hájigak limestone has been sent to Mr. F. R. Cowper Reed, who has kindly undertaken to describe it and its affinities have not yet been determined.[1] In his valuable paper recently published on the subject of pre-Carboniferous Life-Provinces (**24**), Mr. Reed has discussed in considerable detail the relationships of the Indian and Burmese Devonian faunas and his conclusions would lead us to expect one of European type in Afghanistan. Devonian fossils have been found in Chitral between Drosh and Mastuj and again on the Baroghil pass, and it would appear that the Devonian sea which covered Bámián and the Hindu Kush extended through Chitral into the Himalayan region and thence, through Spiti and Byans, into Eastern Tibet and Burma.

Of a Middle Carboniferous fauna we have no record in Afghanistan, for the Helmand series has yielded no fossils, but the latter part of that period and probably also the Permian, is represented in the Khingil series of the Kabul area and by the Fusulina limestone of the Hindu Kush. The Fusulina limestone is of particular interest, since it serves to link the history of Afghanistan with that of many other parts of Asia. The relationship of the fauna to those of similar limestones in other parts of the world has been discussed in a previous paper (**17**, 252); it shows affinities with the Urals on the one side and Texas on the other, whilst the intervening gap is filled by species occurring in Sumatra, Indo-China, China and Japan. Burma has recently been added to this list and I am informed by Mr. La Touche that amongst his collections from the Northern Shan States, which were sent for description to Professor Diener,[2] the commonest species from the Fusulina limestone

[1] See footnote to p. 24.

[2] Professor Diener's interesting description of these collections is now in the press, and will be published in the *Palæontologia Indica.*

is *F. elongata* Shumard, which had previously been recorded only from Texas and Afghanistan. On the other hand, the fauna of the Afghan Fusulina limestone has no apparent affinities with that of the Productus Limestone of the Salt Range, but this may quite well be due merely to our very meagre knowledge of its contents. The late Dr. von Krafft also found Fusulina limestone extensively developed in Darwáz, but here again the *Fusulinæ* were apparently unrelated to Salt Range types (**19,** 58). At the same time there seems to be equally little relationship between the respective faunas of the Fusulina limestones of Darwáz and Bámián; this, however, may also be due to the smallness of the collections from Afghanistan and Darwáz.

Fusulina limestone has not been recorded from Western Afghanistan, but Mr. Griesbach regarded the fossiliferous limestone of Herát and Khorasán[1] as equivalent to that of Bámián. It is found again in Baluchistan (**31,** 162) where, however, it has not been examined in detail and the affinities of its fauna are unknown.

After the formation of the Fusulina limestone, important changes took place in Afghanistan. Except in the hills to the east of the Kabul plain, no Lower Triassic rocks have been found. The Khingil series, which appears to have been deposited in a bay of the Tethys running out from the Himalayan area, is in its upper part only a westerly extension of the Himalayan Trias. Whether this extended further into Western Afghanistan and Afghan Turkistan, it is impossible to say, since no trace of Lower Trias has been found in any part of that region; if it had ever existed, one would expect to find a certain amount of it preserved, yet neither Mr. Griesbach nor I have met to the north or west of Kabul with anything resembling the Lower Trias of the Himalaya.[2]

[1] Among his collections are a hard dark limestone with *Producti*, which exactly resembles the band with *Productus* in the Fusulina limestone of the Khwájagar dara in Bámián; other specimens from Khorasan are very like the brachiopod-bearing limestone of the Kotal-i-Hajigak, which I regard as Devonian. The latter specimens have been sent to Mr. F. R. Cowper Reed, who has confirmed my views as to their age and identity.

[2] Mr. Griesbach's so-called "anthracite series and lower trias" of Saighán has already been shown to be in all probability at least as old as Carboniferous (*supra*, p. 57).

It must be admitted that our knowledge of the geology of Afghanistan is so extremely small that many stratigraphical horizons, which are no doubt present, are still undiscovered, and this may be one of them. In Darwáz the Lower Triassic facies described by Dr. von Krafft is entirely different to the Himalayan, and, as what little evidence there is points to a certain similarity between the respective conditions prevailing in Darwáz and Afghan Turkistan towards the close of the Palæozoic era, I am inclined to regard the Kabul area as the western limit of the Lower Triassic Tethys of the Indian province.

In Darwáz and other parts of Russian Turkistan volcanic activity began in the latter part of the Fusulina limestone period, and traps and tuffs were interbedded with, and succeeded, the limestone without apparent break. Similar conditions may have prevailed in parts of Afghan Turkistan, but there is no evidence of this, and in Saighán there was a marked break in continuity of deposition, for the volcanic beds overlie the older formations with unconformity and overlap; the gap thus produced may perhaps have been filled by Lower Triassic beds, but none such have been found as yet, and the question must remain for the present one of the unsolved problems in Afghan geological history.

This is the second break in the local geological record. It was succeeded by a period of considerable instability characterised by volcanic activity and oscillation between marine and terrestrial conditions. Certain of the beds of dark shale in the Doáb series of Saighán are apparently normal marine sediments, and the accompanying beds of stratified volcanic ash are also evidently of aqueous origin. In other parts of Saighan, however, we find evidence of terrestrial conditions in the local erosion and overlap in the middle of the Doáb series itself. Volcanic beds have not been recorded at any appreciable distance to the north-west, for Mr. Griesbach makes no reference to tuffs or traps in Chahil and Shisha Walang, where the Doáb series appears to be represented by estuarine and shallow-water marine deposits with *Halobiæ* of Upper Triassic aspect. These are the only Triassic marine fossils that have been found in Afghanistan outside the Khingil series and, if truly Triassic, will indicate the extension of the Tethys over parts of Afghan

Turkistan towards the end of that period. The shales and sandstones with which the fossils are associated, and the broken condition of most of the shells, prove them to be littoral deposits.

In Western Afghanistan, in the neighbourhood of Herat, and in Khorasan, the rocks included by Mr. Griesbach under the term "Plant-bearing series" are apparently the representatives of my Doáb and Saighán series and, like the former of these, are associated with volcanic beds. It appears, therefore, that the Triassic period was, at least during its latter part, one of volcanic activity over the greater part of Northern and Western Afghanistan, which formed a barrier between the Indian and European Triassic marine basins. Over this area terrestrial conditions prevailed on the whole, giving place occasionally to marine, owing to incursions of a shallow arm of the sea. Whether this sea was the European or the Indian we have not yet sufficient evidence to show.

In a comprehensive review of the Trias of the Himalaya (**4**, 91), Dr. Diener has referred to Afghanistan as the western extremity of the Indian zoo-geographical region during the Middle and Upper Triassic periods. This assumption was based on the evidence of the Chahil fossils referred by Mr. Griesbach to *Daonella lommeli* and *Monotis salinaria,* and which have now been found to be *Halobiæ* of doubtful affinities and not, so far as we know, referable to any Indian Triassic forms. West of the meridian of Kabul, therefore, there is no unequivocal evidence of the former extension of the Himalayan Tethys over Afghanistan at this period. Frech, on the other hand, includes Western Afghanistan in the European province (*Lethæa mesozoica,* Bd. I, map), which he separates from the Himalayan by a narrow meridional belt embracing Eastern Afghanistan and N. W. Kashmir; this, however, he believes to have been submerged by subsequent transgression of the Triassic sea, which thus finally linked up the two marine provinces. So far as the greater part of the Triassic period is concerned, Frech's view is supported by such additions as have recently been made to our knowledge of the geology of Afghanistan, but we are still without definite evidence of any direct communication between the European and Himalayan seas in Upper Triassic times.

The limestone of Kharwar and Dobandi, which has been referred by Mr. Griesbach to the Upper Trias (rhætic) is said to overlie plant-bearing beds ; it may, therefore, perhaps be an extension of the Khingil series, in which case it indicates south-westerly transgression of the Himalayan Tethys over an older Triassic land-surface. But there is no evidence that this transgression extended to Western Afghanistan, where the Upper Triassic facies is quite unlike the Khingil series and where no Himalayan types have been found.

An argillaceous facies of Upper Triassic age was found by Mr. Vredenburg in Baluchistan (**31**, 162), and the fossils were described by Professor Diener in *Records, Geological Survey of India*, Vol. XXXIV (p. 12) ; they include *Monotis salinaria*, a species of *Halorites* belonging to the group of *catenati continui*, a species of either *Distichites* or *Dittmarites*, also *Celtites*, *Paratibetites* and *Rhacophyllites*. Although *Halorites* is a common genus in the Himalayan Trias, the species found there belong entirely to the *acatenati ;* on the other hand, the *catenati continui* are extremely common in Europe. The Baluchistan form is therefore essentially un-Indian, and is a link with Europe. The species of *Rhacophyllites* also has European affinities, whereas the other ammonites are related to Himalayan forms. Here, then, we have perhaps indications of a "meeting of the waters," and it may have been through Tezín, Kharwar and Pishin that communication was established in Upper Triassic times between the Indian and European marine provinces. At that period Northern and Western Afghanistan appear to have been in a state of instability, resulting in alternate periods of subsidence and elevation, neither probably of any considerable duration or importance and both accompanied by volcanic activity. Subsequently terrestrial conditions were definitely established, and by the middle of the Jurassic period Afghan Turkistan, with Western Afghanistan and Khorasan, were joined to Russian Turkistan, which was the south-westerly extension of Angaraland. After the formation of the Saighán series, which is merely the uppermost member of Suess' Angara series (**29**, 19), Northern Afghanistan appears to have formed part of a great land-locked basin, in which was deposited a thick series of red beds

consisting of conglomerates, grits and sandstones followed by red limestones with hippurites, which indicate a gradual reversion to marine conditions. Subsequent disturbance led once more to the retreat of the sea and the formation of salt-lakes in which gypsum was deposited. This was the third important break in Afghan geological history. It was followed by the great Upper Cretaceous transgression, which resulted in the submergence of vast tracts of Asia, including much of Afghanistan, Baluchistan and adjacent parts of India, but no evidence has yet been found of the extension of the Cretaceous sea into Eastern Afghanistan, although it undoubtedly extended far to the south into Baluchistan and eastwards into Kurram and Tirah.

The close of the Cretaceous period was accompanied by some oscillations of the sea-level and gradual contraction of the submerged area. Evidence of the suppression of marine conditions is seen in the gypsum beds of the Lower Tertiary system in Saighán and Káhmard. After this the sea gradually disappeared, and by the latter end of the Tertiary epoch Afghanistan was a land of great rivers comparable, in the width of their valleys and the extent of their deposits, to those of the Himalaya in the Siwalik age. This constitutes the fourth and last break in the stratigraphical sequence.

V.—SUMMARY.

The facts that we have now at our disposal with regard to the geology of Afghanistan lead us to the conclusion that that country is divisible into two stratigraphical provinces, one of which is represented only in Eastern Afghanistan, whilst the other comprises by far the greater part of the country and embraces most of the northern and western districts. The affinities of the former province are with the Himalayan area, whereas those of the latter are with Western Asia and also to some extent with Europe. The mutual separation of the two provinces seems to have taken place towards the end of the Carboniferous period.

The eastern facies embraces a series of old crystalline schists and limestones which recall Archæan types of the Indian Peninsula and

Burma, but are associated in some manner not yet elucidated with Palæozoic sediments and may possibly be entirely of post-Cambrian age. These are overlain unconformably by a calcareous group which represents partly the Productus Limestone of the Salt Range and partly the Trias (Lilang system and Para stage) of the Himalayan marine province. I call this the Khingil series. It is largely developed between the Kabul plain and Jagdallak, whence it extends northwards across the Kabul river towards Kohistán. From the neighbourhood of Khurd Kabul it may extend south-westwards to Kharwar and the Shutargardan, and south-eastwards into Tezín. The Productus Limestone of the Bazár valley is a link between Eastern Afghanistan and the Salt Range, and it is possible that the massive limestone of the Khyber Pass may also represent the Khingil series.

The stratigraphical relations of the older parts of the northern facies are very obscure, but it appears to begin with the Kálu series, a more or less schistose group of clastic rocks derived chiefly from coarse sediments. This is followed by the hematite and limestone (probably Devonian) of the Hájigak Kotal. Above these are slates and quartzited overlain by limestone containing many *Fusulinæ* in the upper beds. The two latter formations represent the Upper Carboniferous, and the Permian, systems. The Fusulina limestone is covered unconformably by the volcanic Doáb series, which is probably partly Triassic and partly Jurassic; it passes up into the Saighán series, a freshwater group of shale, grit and conglomerate with some coal-seams. This is overlain by the Red Grit series, which is of Lower Cretaceous age. Cretaceous limestone, dating from the great cenomanian transgression, covers the Red Grit series and all older formations; it passes up into shales with gypsum which are tentatively referred to the eocene.

The Lower Tertiary and older beds are overlain unconformably by (?) Upper Tertiary conglomerates in the northern districts and by typical Siwaliks in the eastern. A group of shale and conglomerate, with a few small patches and thin streaks of impure coal, fills the Ghorband valley between Siáh-gird and Parsa and may perhaps be of Middle Tertiary age, but no fossils have been obtained from it.

While the eastern facies belongs to the Himalayan and Indian Province, the Northern finds its counterpart in Russian Turkistán. There is no evident relationship between the older systems of the Hindu Kush and Koh-i-Bábá and the complex of igneous rocks and crystalline schists (altered sediments) that Krafft found below the Fusulina limestone of Darwáz, but further north the pre-Devonian rocks of the province of Syr Darya recall the Kálu series and associated beds of the Hindu Kush and Koh-i-Bábá; I quote Weber's description (**33**, 396): " . . . on observe aussi des dépôts du dévonien . . . . et une assise plus ancienne de grès et conglomerats dépourvus de fossiles. Le long du faîte de partage des eaux on observe un développement de schistes métamorphiques également sans fossiles, se rapportant peut-être au carbonifère ou au dévonien".

Above these in the region of Syr Darya are Devonian limestones with *Spirifer Verneuilii* and other fossils, followed by Lower Carboniferous limestone passing up into and alternating with porphyry and tuff. These again are overlain unconformably by Jurassic grits with lignite. The resemblance of the whole of this sequence to the stratigraphical facies of Northern Afghanistan is very striking. The only discrepancy is the apparent absence from the latter area of any representative of the Upper Palæozoic volcanic series of Syr Darya, Darwáz and Kashmir and the similar absence of the Doáb series from the former.

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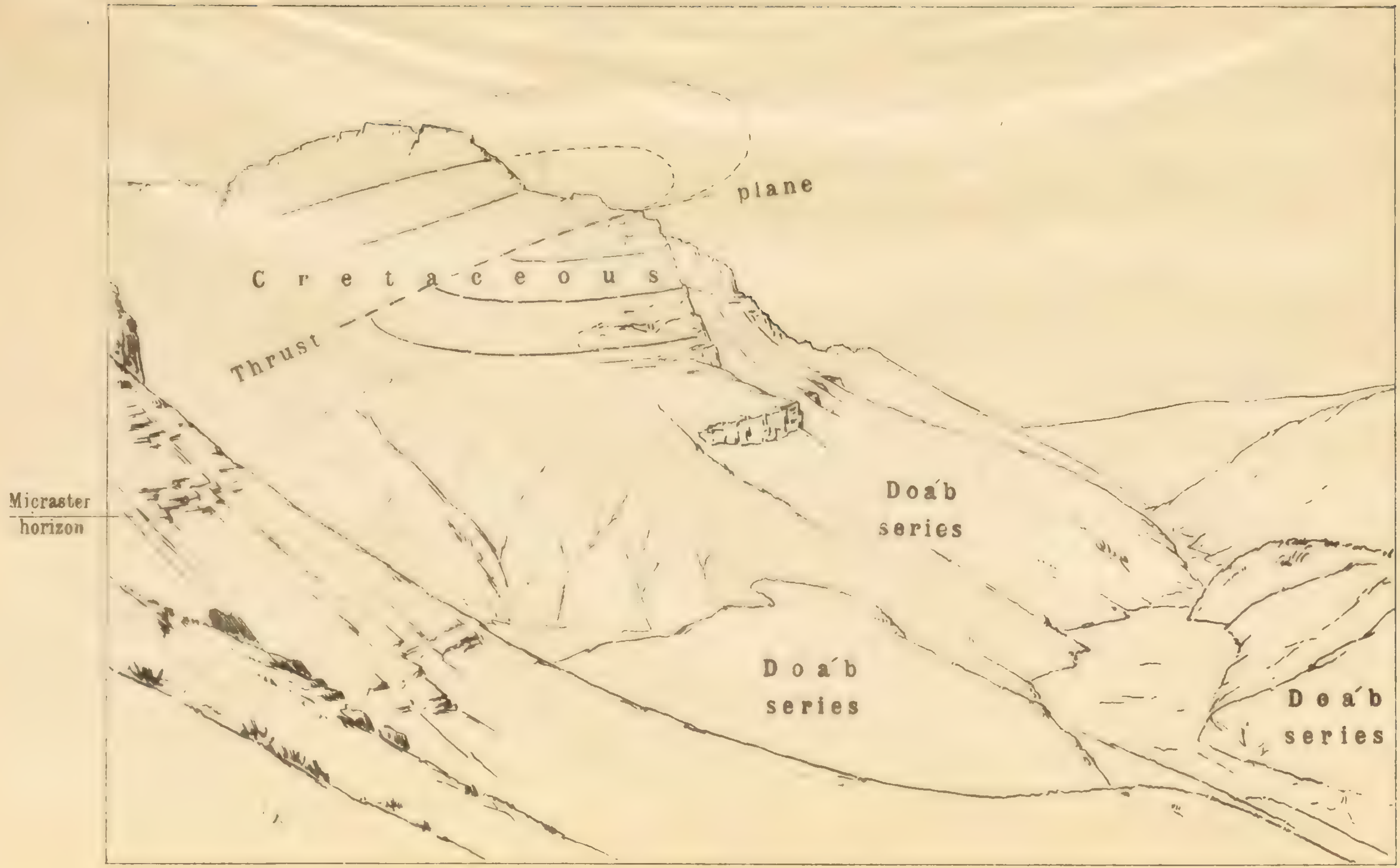
H. H. Hayden, Photo.

RECUMBENT FOLD AT DASHT-I-SAFED.

Plate 3.



Cretaceous
Thrust
plane
Micraster horizon
Doa'b series
Doa'b series
Doa'b series

H. H. Hayden, Photo.

OVERTHRUST IN BEGAL, SAIGHAN.

H. H. Hayden, Photo.

HAJIGAK LIMESTONE AND HEMATITE IN HILLS NEAR KÁLU ROBÁT.
a, Devonian limestone; b, Lower Carboniferous; H, hematite.

H. H. Hayden, Photo.

DOAB AND SAIGHÁN SERIES AT ISHPUSHTA.

H. H. Hayden, Photo.

FOLDED CRETACEOUS BEDS IN LOWER SAIGHAN.

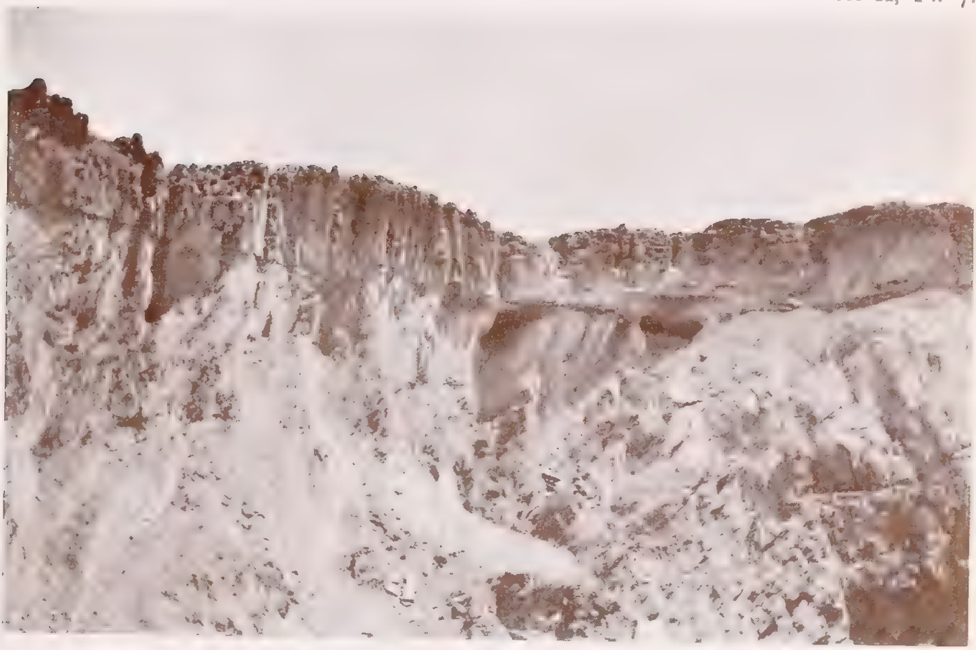


FIG. 1, UNCONFORMITY NEAR SARAIAK, SAIGHAN

H. H. Hayden, Photo

FIG. 2. UNCONFORMITY AT SARAIAK, SAIGHAN.

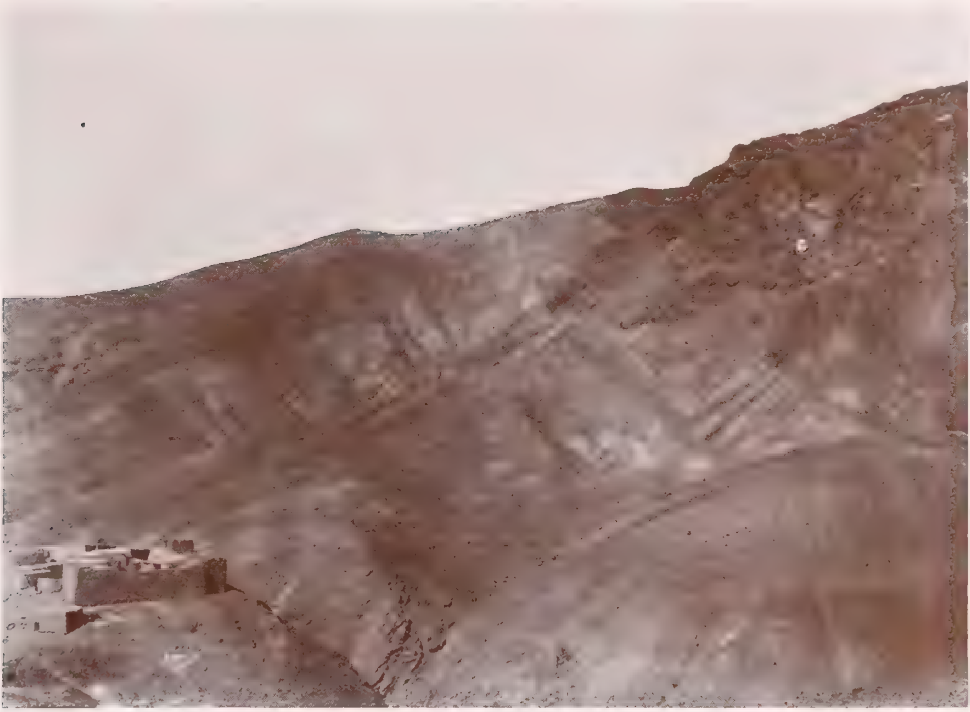


Fig. 1, TERTIARY BEDS UNCONFORMABLE ON GHORBAND LIMESTONE, NEAR FÁRÁGARD.
G, GHORBAND LIMESTONE.

H. H. Hayden, Photo.

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H. H. Hayden, Photo.

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H. H. H[illegible], Pho.

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H. H. Hayden, Photo.

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H. H. Hayden, Photo.

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3, Cretaceous limestone; 2, Saighán series; 1, Doáb series.

H. H. Hayden, Photo.

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H. H. Hayden, Photo.

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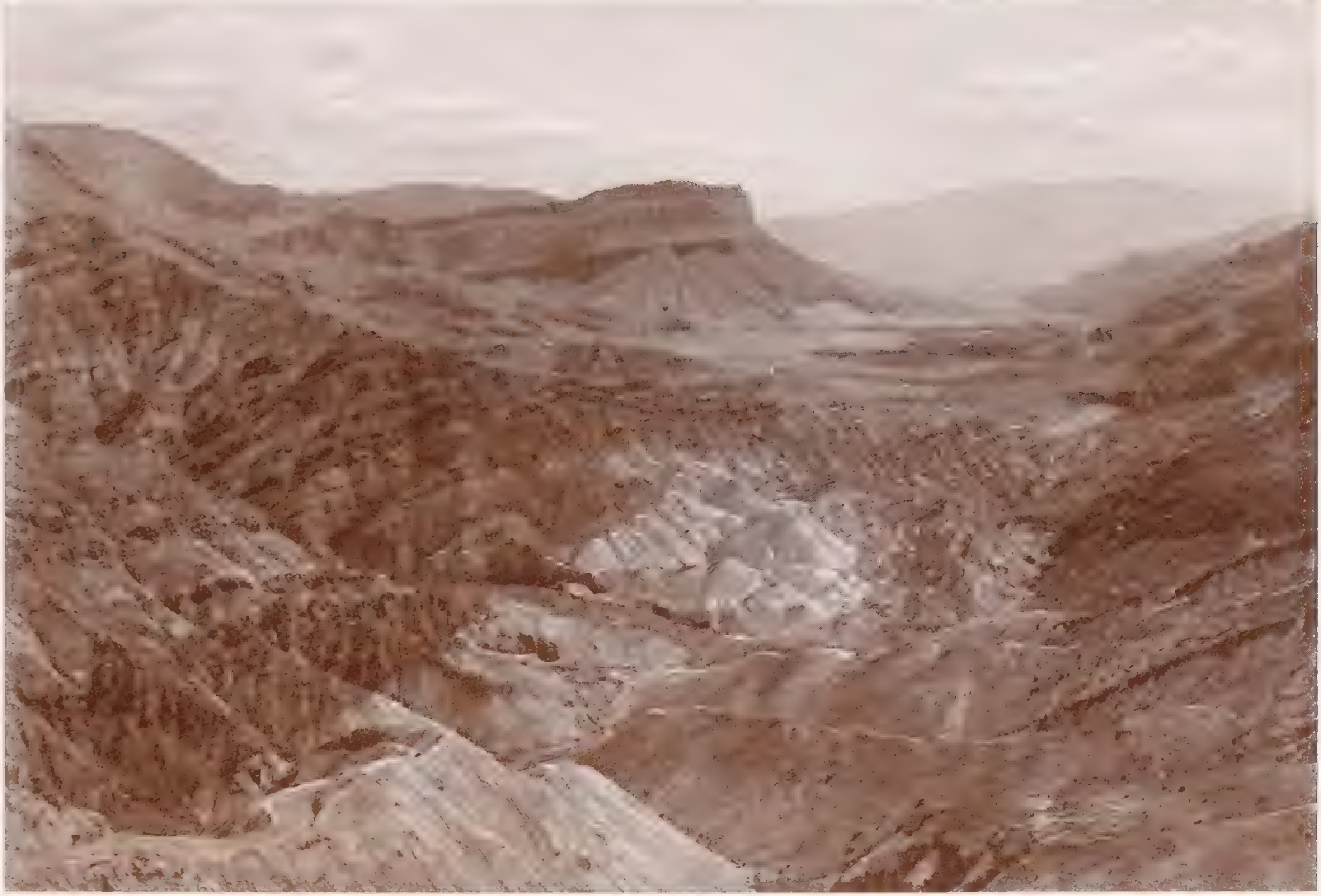

H. H. Hayden, Photo.

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RED GRIT SERIES IN HILL OPPOSITE BARFAK.

H. H. Hayden, Photo.

TANGI BAJGAH.

T, TERTIARY BEDS.

H. H. Hayden, Photo.

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H. H. Hayden, Photo.

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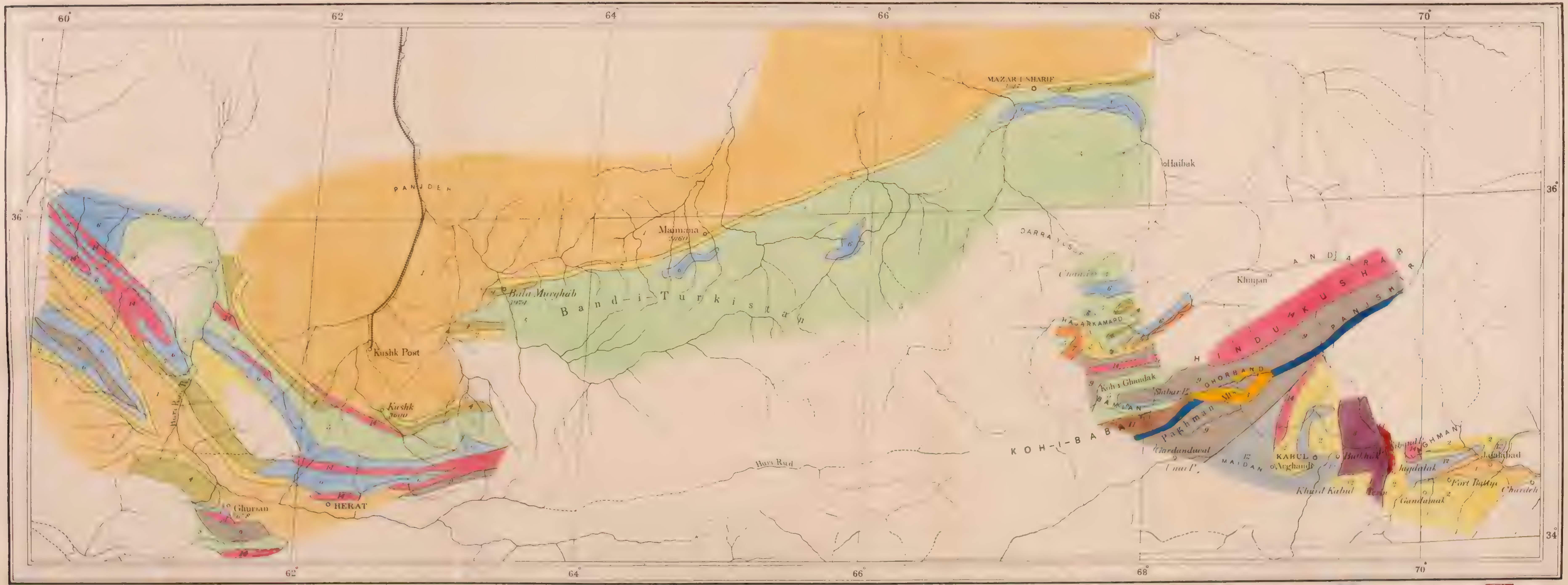

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GEOLOGICAL SKETCH-MAP OF NORTHERN AFGHANISTAN.

(The South-Eastern portion mapped geologically by H. H. Hayden, the remainder by C. L. Griesbach)

(Scale 1 inch = 32 miles.)

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

T. H. D La Touche, Photo.

THE MAN-SANG FALLS.
Namyau River, N. Shan States.

MEMOIRS

OF

THE GEOLOGICAL SURVEY OF INDIA

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GEOLOGY OF THE NORTHERN SHAN STATES. By T. H. D. LA TOUCHE, M.A., F.G.S., *late Officiating Director, Geological Survey of India.*

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1913.

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Map (Eastern Section). Reference *for* Nepeng *read* Napeng.

MEMOIRS

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GEOLOGY OF THE NORTHERN SHAN STATES. By T. H. D. LA TOUCHE, M.A., F.G.S., LATE *Officiating Director, Geological Survey of India.*

CHAPTER I.

INTRODUCTION.

THE main features of the sequence of strata deposited along the Northern shores of the ancient Gondwana continent, and the affinities of the successive faunas entombed in the rocks, have long been made known to us through the researches of numerous geologists and palæontologists,[1] and a general correlation has been established between the geology of that coast and that of the Alps of southern Europe. But up to the present time we have had but little knowledge of the formations that were being laid down contemporaneously with these along the Eastern shores of that continent. The researches of von Richthofen, von Loczy, Bailey Willis, and others,[2] have made us acquainted with the geology of a large part of China, but of these observers Professor v. Loczy alone has carried his researches up to the borders of Gondwana-

[1] For references see Burrard and Hayden, Geography and Geology of the Himalaya Mountains and Tibet; Part IV, by H. H. Hayden, Geology of the Himalaya; Calcutta, 1908.

[2] F. v. Richthofen, China, Ergebnisse eigener Reisen und darauf gegründeter Studien, Vols. II and IV; Berlin (1882): L. v. Loczy, Reise des Grafen Bela Szechenyi in Ostasien, Vols. I and III; Vienna (1899): F. Leprince-Linguet, Etude Géologique sur le Nord de la Chine; *Ann. des Mines*, Ser. 9, Vol. XIX, p. 346 (1901): Th. Lorenz, Beiträge zur Geologie und Palaeontologie von Ostasien; 1 Teil., *Zeitschr. d. Deutsch. Geol. Gesellsch.* Bd. LVII, p. 438; 2 Teil., Bd. LVII, p. 67 (1905 and 1906): C. D. Walcott, Cambrian Faunas of China; *Proc. U. S. Nat. Mus.*, Vols. XXIX, XXX (1906): Bailey Willis, Research in China; Carnegie Institution, Washington (1907): H. Lantenois, Mission Géologique et Minière du Yunnan Meridional; *Ann. des. Mines*, Ser. 10, Vol. XI, p. 298 (1907): A. F. Legendre & P. Lemoine, Grandes Lignes de la Géologie de Pays Lolo; *Bull. Mus. Nat. D'Hist. Naturelle*, No. 1, 1910, p. 59.

land, and he crossed the boundary at only one point, between Ta-li-fu in south-west Yunnan and Bhamo in Upper Burma. In Yunnan he found a series of rocks which, as the following pages will show, correspond very closely with those of the Shan States; including representatives of the lower Silurian or Ordovician, Middle Devonian and Permo-Carboniferous Systems, succeeded by a series of red beds ranging in age from Permian to Jurassic. And his observations have been so far supplemented by those of the French geologists employed on the survey of the country in advance of the railway which has now been carried up from Tongking, and by those of my colleague Mr. Coggin Brown,—who had the advantage, before he visited Yunnan, of making himself acquainted with the geology of the Northern Shan States,—that it is possible to correlate, with a certain amount of confidence, the formations in these two areas with each other, and consequently with those of Central China; and to infer that they were accumulated under similar conditions and in a single sea basin.

Relations with Gondwanaland.

There can be little hesitation, I think, in accepting the assertion that the crystalline complex of Archæan rocks, on the borders of which these sediments were accumulated, once formed an integral portion of the Gondwana continent, though they are now separated from the Indian Peninsula by a great depression, filled for the most part by Tertiary and recent deposits. The Archæan rocks of the Himalaya, which are now acknowledged to have formed a part of Gondwanaland,[1] are now separated from those of the Peninsula in a precisely similar manner by the broad Indo-Gangetic plains, and I think that there is evidence to show that the separation in each case took place at about the same period (*see below*, p. 351 *seq.*). An account of these depressions, their significance and their cause, has been given by Professor Ed. Suess,[2] who designates them by the name of 'foredeeps' (*vortiefen*).

Previous notices.

The references to the Shan States in the geological literature of Burma, before the year 1887, are of a very meagre description, and are almost entirely confined to an enumeration of the useful minerals that were supposed to occur on the plateau in great abundance. These minerals are always mentioned in the accounts of the embassies that were

[1] H. H. Hayden, *op. cit.*, Vol. IV. pp. 221, 227.
[2] Das Antlitz der Erde, Vol. 1, Chap. XII. Vol. III, pp. 335, 581.

despatched by the Government of India to the Court of Ava between the years 1795 and 1855;[1] but none of the members of any of these missions was allowed to visit the plateau, and it must be confessed that, with the exception of the ruby mines of Mogôk and the silver-lead mines of Bawdwin, the reports of the existence of vast mineral wealth have not been verified by recent surveys. The only early account of any of these occurrences that we possess, written by an eye-witness, is that of Père Guiseppe d'Amato,[2] who was permitted to visit the Ruby Mines at some time before the year 1833. He describes the native methods of working the mines, and mentions the discovery of two masses of ruby, one of which he was assured, as he says by a person of the highest credit, weighed more than 80 pounds.

Dr. T. Oldham, 1855.

The last of these missions, that of Major Phayre in 1855, was the only one accompanied by a geologist, Dr. T. Oldham, then Superintendent of the Geological Survey; but he was unable to ascend to the crest of the Shan plateau, though he paid a flying visit to the summit of a hill called the Myaleitdaung, "whose broken outlines," as he says, "and boldly scarped sides form so prominent a feature in the landscape," looking eastwards from Amarapura, which was then the capital;[3] but he could only observe that the hill was formed of limestone, dipping west at 50 to 60 degrees, and that the hills rising from the plain to the north were composed of similar rock with the same inclination westwards. He was unable to discover any fossils.

F. Fedden, 1864-65.

During the field season of 1864-65 Mr. F. Fedden[4] of the Geological Survey travelled through the Shan States from south to north, entering the hills near Yamethin, 110 miles south of Mandalay, and marching north-eastwards to Kehsi Mansam (**H** 5),[5] on the southern border of the

1 M. Symes, Embassy to Ava in 1795; London (1800), p. 324. J. Crawfurd, Account of the Mission to Ava in 1827; *Edin. New Phil. Journ.*, Vol. III (1827), p. 364. Journal of an Embassy to the Court of Ava in 1827; London (1829), pp. 427, 441. H. Yule, Narrative of the Mission to the Court of Ava in 1855; London (1858); Appendix A, by Dr. T. Oldham, p. 344. S. F. Hannay, Productive Capacities of the Shan Countries; *Sel. Rec. Beng. Govt.*, No. XXV, p. 10.

2 The Mines of Precious Stones in the District of Kyatpen; *Journn. As. Soc. Bengal*, Vol. II, p. 75.

3 *Op. cit.*, p. 336.

4 Journal of the Salween Surveying Expedition; *Sel. Rec. Govt. India*, No. XLIX, p. 30.

5 These letters and figures denote the squares into which the map is divided.

northern States, and thence to Lashio (**H** 1). After an attempt to reach the Salween valley by way of the Námyau, he returned to Lashio, travelled through South Hsenwi *viâ* Möng Yai (**I** 3) to the Salween at Mánkat (Soo-kat), and descended the river, partly on rafts, to Takaw ferry, whence he returned across the plateau to Hlaingdet in the Sittang valley. A geologically coloured map is attached to his report, but no attempt is made to co-ordinate his observations, which merely record the rocks seen each day along the route. He mentions no fossils, though he speaks of the limestone at Kehsi Mansam, or Ban Zam as he calls the place, where the outcrop is filled with bryozoa and corals. But as the party travelled with elephants, and if possible, carefully avoided any hilly ground, it is not surprising that he found nothing of greater interest than the monotonous limestone of the plateau. It is more strange, however, that he does not allude to the existence of coal, as it is clearly visible in the bank of the river at Mán Sé (Ban Zé) (**H** 1) where he crossed the Nám Pawng, in the Nammá coal-field, on two occasions; while he traversed the Lashio field from end to end.

C. Barrington Brown, 1887.

The expedition of Mr. C. Barrington Brown to the Ruby Mines in 1887 was undertaken for the purpose of ascertaining the value of the mines on behalf of the Secretary of State for India, and his observations were confined to the belt of crystalline rocks adjacent to the road from Thabeikkyin on the Irrawaddy to Mogôk (**C** 1). His report on the mode of occurrence of the rocks met with and on the methods of working the mines, coupled with a masterly description of the petrological types collected and a discussion of the origin of the gems, contributed by Professor J. W. Judd,[1] remains the most complete account which we possess regarding the character and relationships of the Archæan rocks of this region, and I owe the greater part of the description of the crystalline series that I have given in this Memoir to that paper.

Dr. F. Noetling, 1890

The first connected account of the geology of the Northern Shan States is contained in a report by Dr. F. Noetling on the results of an expedition undertaken in 1890 with the primary object of ascertain-

[1] The Rubies of Burma and Associated Minerals: their Mode of Occurrence, Origin, and Metamorphoses. A Contribution to the History of Corundum. *Phil. Trans. Roy. Soc. London*, Vol. 187A, p. 151.

[2] Coal-fields in the Northern Shan States; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 99.

ing the economic value of the coal seams then recently discovered in the Námyau and Nammá valleys. Dr. Noetling's journey was made at an unfortunate time of year for geological observations; for he visited the country during the rainy season, when everything is buried in a mass of rank vegetation, and the mule tracks, which were at that time the only means of communication, are almost impassable. A cart-road was then being made from Mandalay to Maymyo (**C** 4), 40 miles distant on the plateau, and it was in this portion of his journey only that Dr. Noetling found any fossils. In addition to these drawbacks, the only map to be had was one on a scale of sixteen miles to an inch, and by no means accurate. Whereas when Mr. Datta and I made our first traverse, ten years later, the cart-road had been extended to Lashio, and the earth-work for the Mandalay-Kunlon railway had also been completed as far as that place; consequently we had the advantage of numerous and freshly opened cuttings, which greatly facilitated our observations. Moreover, after the first season we were supplied with excellent maps, on the adequate scale of one mile to the inch.

Physical features.

Dr. Noetling prefaces his account of the geology by some remarks on the topographical features of the plateau, but I cannot say that his conclusions about the peculiar arrangement of the river valleys have withstood the test of more recent investigation. He says (*Op. cit.*, p. 101):—

"The boundary which separates the plateau-like south from the hilly north of the country here described is marked by a long valley, which begins a few miles east of the Gokteik pass and runs in a north-eastern direction to the Salween, and probably far beyond it to Western China. This valley has the peculiar feature that it has not one general direction of drainage but three, at least so far as I have examined it. Beginning from the Salween, we see the water running to the east up to a village called Hoika about 30 to 35 miles east of Lashio. Beyond that village the water runs to the west as far as Bawgyo, where it is met by a stream coming from the west, joining the waters coming from the east. This irregularity —the direction of drainage—proves that the origin of this valley must be a peculiar one, and so it is. The Gokteik-Kunlon valley marks a line of great disturbance of the strata; two large faults, or probably two systems of compound faults, running from the south-west to the north-east, are distinctly discernible. Along these faults the country was thrown down, but as this action did not of course take place very regularly, one part moving perhaps stronger than another, the peculiarity of the drainage system is readily explained. It is very common in this valley to meet isolated hills rising abruptly in its centre; they are nothing

more than small parts of the sinking blocks which have become jammed. Sometimes they still touch both sides of the valley, forming a kind of bar or ridge. Such bars, breaking seemingly the continuity of the valley, are numerous and of smaller or larger extension, and they account also in some degree for the direction of the drainage. A most perfect instance of such a bar may be seen between the villages of Manpeng and Meungyaw. Here the bar has a length of about 5 miles; the breadth may be about the same. The bar consists of red sandstone, resting on blue limestone, while the hills on both sides are formed of blue limestone. Thus the lateral boundary between red sandstone and blue limestone is as distinct as possible, proving plainly the existence of a fault on either side of the bar. Similar bars may be seen east and west of Lashio, but I have never noticed them so clearly discernible as in the instance quoted above."

With the exception of the short stretch of the Nám-Tu valley between Námhsim and Hsipaw (**F** 2), where a large block of red sandstones is let down by parallel faults, one bounding the river valley on the north, and the other passing through Loimawk, on the southern side of the hills south of Bawgyô, the existence of two systems of parallel faults extending the whole length of the Nám-Tu and Námyau valleys north-eastwards from Hsipaw has been found to be purely imaginary. The so-called 'bar' extending across the valley of the Námyau below Mong-yaw is not a portion of the red sandstones jammed between two lateral faults, but is a continuation of the band which arises immediately to the east of Lashio, and may be traced far to the north-east across the Námyau valley, flanked by the 'blue limestone' in parallel sequence on either side. In fact, from the Salween to Hsipaw, the structure is an ordinary succession of folds, striking from north-east to south-west, across which the rivers have cut their valleys more or less diagonally. Only one fault of importance has been noticed in this part of the river course, *viz.*, at Manlong-Mansang, and this crosses the river almost at right angles. There certainly are peculiarities in the drainage system of the plateau, but they seem to be due to the capture by the Nám-Tu, which now drains practically the whole area, of the waters that once perhaps flowed eastwards into the Salween.

Dr. Noetling's classification.

Dr. Noetling classifies the formations met with by him according to the following list, in descending order:—

6. Alluvial formation, including river deposits and hill clay.
5. Tertiary formation, probably younger miocene.
4. Red sandstones of undetermined age.

3. Palæozoic formation, ranging probably from the cambrian to the upper silurian system.	Upper group: Pyintha limestone with fossils of lower silurian age. Lower group: Mandalay limestone without fossils.

2 Submetamorphic formation.

1. Gneissic formation.

Volcanic rocks: Porphyry of unknown age, granite of gneissic age.

Palæozoic formations.

The gneissic and submetamorphic formations of this classification need not be discussed now, but the palæozoic formation requires a brief notice. Dr. Noetling includes in his lower group, the Mandalay limestone, not only the crystalline limestones of Mandalay Hill and other isolated hills in the Irrawaddy plain, but also the limestones forming the western slopes of the edge of the plateau, and the great bulk of those on the plateau itself. But the discovery of fossils, including *Fusulina*, at the very edge of the scarp close to Tonbô (**B** 5), has proved that these limestones are of very much later geological age than those of Mandalay and the Sagyin Hills, which belong to the gneissic series of Mogôk. And the whole of the great limestone formation of the plateau has now been shown to belong to the Devonian and Carboniferous systems, and therefore to be of later date than Dr. Noetling's Pyintha limestone. This latter group also has been found to be only one member of a series of Ordovician rocks, which are well exposed in the broken country along the western edge of the plateau. A single determinable fossil was found by Dr. Noetling in this limestone, and enabled him to fix the age of the bed correctly as that of the lower Silurian (Ordovician) of northern Russia; though his identification of the fossil as an *Echinosphærites*, and his description of it under the name of *E. Kingi*,[1] have now been shown to be erroneous.

Red sandstones.

The 'red sandstones of undetermined age,' which occupy a far larger area than was supposed by Dr. Noetling, have now been found, on the evidence of fossils contained in interbedded bands of limestone, to be of

[1] Field Notes from the Shan Hills; *Records, Geol. Surv. Ind.*, Vol. XXIII, Pt. 2, p. 78.

Jurassic age. In justice to Dr. Noetling, however, it must be admitted that none of the limestone bands appear at all on the route which he followed, and that the sandstones themselves seem to be almost without fossils.

Tertiary formation.

Regarding the Tertiary formation, with its coal seams, Dr. Noetling was strongly inclined to the opinion that these beds had been preserved by being let down between his imaginary faults, and that they were confined to those valleys which run from south-west to north-east. Recent surveys of these coal basins, however, have shown that the silts in which the coal seams occur were deposited after the present system of hill and valley had been carved out; also that the valleys to which they are confined radiate from the highest ground on the plateau, and have no common direction. Dr. Noetling appears to have been in considerable doubt regarding the age of these beds, for in his list of formations he alludes to them as 'probably younger Miocene,' whereas elsewhere (*Op. cit.*, p. 106) he speaks of them as of late Tertiary age. The latter supposition is probably correct, since the only fossils associated with the coal seams possess a very recent geological aspect.

Porphyry.

The pebbles of 'porphyry' mentioned by Dr. Noetling as being found in the bed of the Nammá river are derived from rocks belonging to the Bawdwin volcanic series, which are *in situ* on the southern side of the valley higher up.

Traverse of 1899-1900.

During the field-season of 1899-1900 a systematic survey of the Northern Shan States was begun by my colleague Mr. P. N. Datta and myself, with a traverse along the cart-road and the railway line then in course of construction from Mandalay to the Salween. The results of our investigations were published separately in the General Report of the Geological Survey for that year, and as a natural consequence there are certain discrepancies in the interpretations which each of us gave to our observations. Moreover, the open season was no more than long enough to enable us to journey directly across the plateau and back again; and as the railway and cart-road avoid the broken ground as far as possible, more than one formation of great importance escaped notice altogether or was very inadequately described. Thus there are many imperfections in these preliminary reports, and in some cases serious alterations and

additions have had to be made in our original lists of formations. For instance, the 'Tonbo Series' of Mr. Datta, which both of us placed at the base of the fossiliferous sequence, has since been shown to be identical, at least in part, with the limestone of the plateau, and to be younger than the Silurian. Again, one very important formation of Silurian age, the upper Námhsim marls, which is touched at only one point by the railway, and at another on the cart-road, received very little attention; while the lower part of the same formation, the Námhsim Sandstone, escaped notice altogether.

Modifications of our preliminary investigations were made in subsequent General Reports of the Geological Survey, but as they are now superseded by the present Memoir there is no need to refer to them in detail here. Mr. Datta was associated with me in the survey until the year 1903, and I have been assisted at different times by my colleagues Dr. G. E. Pilgrim and Mr. Coggin Brown, references to whose work will be found in the following pages.

General considerations.

Even now the present Memoir must be considered, not as a complete account of the geology of the Northern Shan States, but merely as a preliminary attempt to bring into order the observations made by my colleagues and myself; to furnish a basis, which I can only trust may be found to possess a certain degree of stability, on which future geologists may work; and to connect, as far as possible, the geology of this interesting tract with that of the surrounding regions. The area dealt with in these pages is almost twice the size of that of Wales, and it contains a sequence of rocks that for variety and complexity of structure may be compared with those that are found in that country, but with very few facilities for observation. It is covered for the most part with forest, or with grass so tall and dense that it is often impossible to force one's way through it; traversed by few roads, and those constructed at the least possible cost, and only driven through rock when it is absolutely necessary, while the same may be said of the only railway; while the mule tracks, the usual means of communication, are little better than footpaths. There are no quarries, which are of so great assistance in countries where stone is used for building and road-metalling, for every house is built of timber or bamboo mats; and there are very few

natural cliff-sections that enable one actually to see the superposition of the strata. It must be remembered also that the time spent in the field has been confined to less than six months in each year, over a total period of only seven years, and has been barely more than sufficient to allow rapid traverses from point to point, leaving little time for the study of details; and that it has often been found impossible to revisit a locality or section, even when observations made in other places have shown that the first impressions formed required modification. Indeed I may say that until the last day of my sojourn in the country, I was continually coming upon fresh facts that caused me to alter, to a greater or less degree, opinions I had previously formed; and even during the writing of this Memoir I have at times felt much regret that I was unable to revisit some of the sections, in order to clear up doubts that work in the laboratory has forced me to entertain regarding my interpretation of certain questions.

Palæontological researches.

Imperfect as it is, this account of the geology would have been a mere shadow of itself, if I had been deprived of the assistance which I have received and most gratefully acknowledge, from the labours of the distinguished palæontologists to whom the collections of fossils made by my colleagues and myself have been entrusted for description, Miss M. Healey, Mr. F. R. Cowper Reed, Dr. C. Diener, and Mr. S. S. Buckman. The results of their researches, published in the *Palæontologia Indica*,[1] are of the utmost value, and the following pages will show to what an extent I have drawn upon them for my interpretation of the geological sequence. The material placed at their disposal was often, I fear, of a most difficult and ill-preserved nature; but the consistent character of the results achieved are an abiding testimony to the enthusiasm and skill which have been devoted to the work.

In conclusion, I have only to express a hope that others will take up the work, and fill in the details of this sketch. There is no part of India, indeed I may say of southern Asia, which is at the same time so accessible to the geologist, and presents so great and varied a sequence of fossiliferous formations as this

[1] F. R. Cowper Reed, The Lower Palæozoic Fossils of the Northern Shan States; *Pal. Ind.*, New Ser., Vol. II, Mem. No. 3; The Devonian Faunas of the Northern Shan States; *ibid*, Mem. No. 5: Miss M. Healey, The Fauna of the Napeng Beds or the Rhætic Beds of Upper Burma; *ibid*, Mem. No. 4: Dr. C. Diener, Anthracolithic Fossils of the Northern Shan States *ibid*, Vol. III, Mem. No. 4.

plateau. In order to reach similar ground in the Himalaya it is necessary to travel over a thousand miles from the sea-board by rail, and then march for many days by slow stages through the outer hills, before reaching the field of operations. Even then the fossiliferous strata must be sought along the faces of mighty precipices in an extremely rarefied atmosphere, where physical powers of no mean order are requisite, in conjunction with a trained head and steady nerve, to preserve the collector from accident; and although the magnificence of the scenery is some compensation for these drawbacks, the labour and expense of such an expedition is sufficient to deter all but a few, and those for the most part professional geologists, from attempting it. In the Indian Peninsula the only easily accessible fossiliferous rocks are the plant beds of the Gondwana coal-fields; and though I would not depreciate the interest and systematic value of such relics of the past, there is no comparison, in my mind at least, between the satisfaction, or I would rather put it the joy, of collecting specimens of leaves, and that of knocking out with the hammer a trilobite or a graptolite.

In the Shan States the conditions are much more amenable. The railway journey from Rangoon, which is connected with Liverpool by a direct and excellent line of steamers, to Maymyo, on the plateau itself, is only one of 428 miles. It is possible to visit some of the most prolific and interesting fossiliferous localities by leaving Mandalay in the morning and returning to one's hotel the same evening; while by means of the railway most of the geology of the plateau can be studied in comfort, and a little forethought and arrangement will enable the geologist to visit places at a considerable distance from the line. It is a delightful country to travel in, one of open park-like savannahs watered by clear rivers, whose waters afford fair sport to the angler, and whose banks furnish the most pleasant camping grounds. It is inhabited by a peaceful, hospitable people, industrious in their own way and much addicted to trade, who, if the traveller can find no open spot on which to pitch his tent, will freely place the enclosure of their picturesque monasteries or pagodas at his disposal, and are generally willing to assist him. The ethnologist would find a wide field of research open to him here, for types of several races and tribes may be met with in the course of a single day's journey; and equally so the zoologist and botanist, for these subjects have hardly

yet been seriously studied on the spot. The climate, for at least five months in the year, is superb, and even during the rainy season it is so superior to that of the plains that the Local Government has established its head-quarters at Maymyo.

With all these advantages, it is my sincere hope that other geologists, and not only those whose professional duty it is to carry on our work, may be induced to visit the country. Among the points of detail that still remain to be worked out I may mention: the stratigraphical position, distribution and significance of the Bawdwin volcanic series; the age of the Chaung Magyi quartzites and slates—Dr. Noetling's submetamorphic formation; the distribution of land and sea at the close of the Ordovician period and the question whether any considerable orographic movements took place at that time, concerning which I have many doubts; and from a zoo-geographical point of view, the reason why we have, among these older rocks, so many anomalous features in the distribution of the faunas in what is apparently a conformable sequence of strata. The staff of the Geological Survey is so small, and the area as well as the number of questions that we have to deal with is so large, that it is with difficulty that one man alone can be spared for such work; and yet I am convinced that if these and other details of the geology of this tract could be fully studied, they would give us a valuable clue to the geology of the whole of south-eastern Asia.[1]

[1] NOTE.—A few words may be added on the pronunciation of Burmese and Shan place-names. The accent is invariably placed on the last syllable; thus Maymyo is pronounced as two syllables, *May-myóo*, not *May-my-ô*. Ky (as in *Kyauk*, a stone or rock) should rather be transliterated Ty, but Europeans generally give it the sound of *ch* in *church*. Gyi (=great, also the name of the barking deer, perhaps given to it in derision, on account of so great a voice proceeding from so small an animal) is pronounced like the French *j'y* in *j'y suis*, and *g* followed by a *y* is always soft. *Y* following *m* is always—and *t* or *k* in the middle of a word are usually—suppressed, as in Myitnge, Wetwin, Gokteik (pronounced *Min-gáy*, *We-wín*, *Go-teek* respectively). Finally, the modified *ō* in Mōng is pronounced as if it were written *Maing*; and Loi (a hill) as two syllables, *Lô-ai*.

CHAPTER II.

PHYSICAL GEOLOGY.

Position and extent.

Nearly the whole area of the Northern Shan States is comprised in sheet 4 S. W. of the quarter inch map of the Burma Topographical Survey, lying between Lat. 22° and 23° N., and Long. 96° and 98° E. Along the western edge of the plateau a portion lies in the Mandalay Division, but the rest is occupied by the Native State of Hsipaw with its dependencies Tawng-peng and Möng Lông on the north, and Möng Tung on the south, and by North and South Hsenwi.

The plateau.

Over the greater portion of this area the plateau-like character of the country is well marked. On the west the hills rise boldly from the plains of the Irrawaddy, forming, as seen from Mandalay, an almost unbroken line of jungle-covered scarps extending, as far as the eye can see, from north to south and reaching, in the neighbourhood of Maymyo, that is, in a distance of about 23 miles as the crow flies, an elevation of about 4,000 feet above the sea. It will be noticed, on making the journey between the two places by railway, that the ascent is not altogether abrupt, but proceeds by a series of steps, of which the most conspicuous is that between Zebingyi and Thondaung stations. The more or less level stretches of ground between these various ascents, such as the one on which Zebingyi station stands, are, as will be seen in the sequel, portions of the main plateau that have been let down by a succession of parallel faults, running in a north and south direction.

General features.

Beyond Maymyo, although the word plateau is generally used to designate the aspect of the country, it is by no means a dead level, in fact there is very little really level ground over the whole area. The surface may be more correctly described as undulating, not unlike that of the 'downs' of Southern England, with a tendency to the formation of more or less gently sloping expanses of even ground, but seldom actually level for any considerable distance. From Maymyo eastwards the

general elevation gradually falls to the plain in which Hsum-Hsai (Thonzé) (**C** 3) is situated. East of this there is an abrupt rise, crossed by the railway at Kyaukkyan, to the Nawnghkio plateau, which is traversed from north to south by the profound and narrow canyon known as the Gokteik (*Shan*, Ho Küt) Gorge. This plateau extends as far east as Pyaung-gaung and Kyauk-mé (**E** 2), beyond which there is a gradual descent, flanked both to the north and south by high ground, to the valley of the Nám-Tu (*Burm.*, Myitngé) at Hsipaw (**F** 2). South and east of this place the country is very hilly, but beyond these hills again a plateau extends from the Nám-Tu to the lofty peaks of Möng Tung in the south-east, to Loi Ling (8,771 feet, the highest mountain on the plateau) (Plate 1) and the ranges bordering the Salween on the east, and, with some breaks, to the north-east beyond Lashio.

Rock formation.

Practically the whole of the area that may be called 'plateau' is occupied by one formation, a dolomitic limestone of Palæozoic age, which will be more fully described hereafter, and it is to the peculiar form of disintegration which this rock has undergone that the main features of the plateau are due.

Boundaries of the plateau.

To the north the plateau is bounded by a tract of exceedingly hilly country, in which the rocks are entirely of pre-Devonian age. The boundary is very irregular. Starting from Maymyo, which it approaches very closely, it turns abruptly north to Kalagwé (**C** 2), on the road to the Ruby Mines, from which point it runs south-east, to the head of the Gokteik gorge. From here it runs north in zigzag fashion till the Námhsim is reached beyond Pyaung-gaung (**E** 3), and then, crossing this river and the Nám-Tu above Hsipaw, it extends, parallel to the latter river, for an unknown distance to the north-east. The boundaries of the eastern portion of the plateau, in the neighbourhood of Lashio, are not so well defined, for in this direction the limestones are thrown into more or less regular folds, and, in association with the older palæozoics, form high ranges of hills. Even here, however, whenever the limestones cover any large stretch of country, they have a tendency to form broad undulating expanses, recalling all the features of the main plateau.

Southern boundary.

To the south the plateau merges into that of the Southern Shan States, the geology of which is only imperfectly known. For a long distance eastwards from the edge of the plateau near Mandalay, the boundary of the Northern States follows the profound gorge of the Nám-Tu, to the point where this river turns northwards towards Hsipaw. Beyond this there is no well-defined physical boundary, the line being drawn entirely for political purposes.

River system, the Nam-Tu or Myitnge.

The river system of the plateau is not very complicated. Nearly the whole area is drained by one river, the Myitngé of the Burmese, or Nám-Tu of the Shans, and its affluents. This river takes its rise in the State of North Hsenwi, in Lat. 23° 20′, Long. 98° 15′, within 20 miles of the Salween. It at first flows westwards to Mong-tát, in about Long. 97° 30′, where it turns abruptly to the south, and traverses the hilly country north of the plateau in a deep and very narrow valley, issuing from these hills a few miles to the north of Hsipaw, in Lat. 22° 37′. It is then joined by a large river from the north-east, the Nam-má, which unites the waters of three considerable streams, the Nám-mi, draining the hills to the north, the Nám-yau, and the Nám-pawng, both of which rise among the hills to the east of the plateau, within a short distance of the Salween. Below the junction of the Nam-má with the Nám-Tu, above Hsipaw, the combined rivers follow the direction of the former, *i.e.*, south of east, to Bawgyô (**F** 2), where another large tributary, the Nám-hsim, coming from the State of Tawng-peng to the north, joins in. There is, however, some evidence to show that in former times the Nám-Tu, instead of joining the Nam-má above Hsipaw, as it does at present, followed an independent course from the point where it leaves the hills at Ta-ti ferry, 6 miles north of that place, to Bawgyô. An account of the supposed change in the course of the river, and the causes that led to it, will be found in the *Records* of the Geological Survey (Vol. XXXIII, Pt. 1). The original bed of the river seems to have been raised by an accumulation of boulders and gravel in front of the point where it leaves the hills at Ta-ti, until it reached such a height that the river broke through the sandstone hills to the south-east along a ravine excavated by two small side streams flowing into the Nám-Tu and Nam-má respectively, and deserted its former channel.

Change in course of river.

Lower course of river.

At the mouth of the Nám-hsim the main river again turns to the south, and flows in a gradually deepening channel to the southern border of the States, in about Lat. 22° 15′, Long. 97° 15′. Here it receives a large stream from the south-east, the Nám-hka, which drains the northern and western flanks of the lofty isolated mass of Loi Pan, in the sub-state of Möng Tung. It then again runs westwards to the lower end of the Gokteik gorge, where it is joined by the Nám-panhsé, which, coming from the north-west, drains with its numerous small tributaries the hilly country to the south of the Ruby Mines District. At this point the Nám-Tu again turns due south, for about 24 miles, and then flows westwards, with a very irregular course, issuing from the hills at Kyetnapá, about 14 miles south-east of Mandalay. Below the mouth of the Gokteik gorge it receives no tributaries of any importance, except the Hpawng-aw, which drains the plain of Hsum-Hsai, and is joined, not far above its confluence with the main river, by the Ke-laung, which rises at Maymyo.

Gorge of the Myitnge.

It was mentioned above that, below the mouth of the Nám-hsim, near Bawgyô, the valley of the Nám-Tu gradually becomes deeper. At Tong-ang ferry, 20 miles to the south, the river already runs between lofty cliffs of limestone rising to between 200 and 300 feet above the water, but below this the channel becomes a profound, narrow gorge, with nearly, often quite perpendicular sides, through which the water dashes in a succession of foaming rapids and long, deep, gloomy pools, to which the light of the sun seldom penetrates, except at mid-day. At the mouth of the Gokteik gorge the channel has reached a depth of about 2,000 feet, but from here the fall does not increase so rapidly, though the river is nowhere navigable except for short distances by dug-out canoes or bamboo rafts.

Recent development of river course.

One or two points of special interest regarding the development of this river may be noted. In the first place its course is almost entirely confined to the formation known as the Plateau limestone. In only one portion of its course, in the long meridional traverse to the north of Hsipaw, does it run for any considerable distance through the older Palæozoic rocks underlying this limestone, though in the deep gorge below Tong-ang it cuts transversely through them

in more than one place. It may be observed that, throughout the gorge above Hsipaw, the course of the river is parallel to a great overthrust fault, which strikes almost due north and south through the rocks at a short distance to the west, and that the plane of this fault is inclined eastwards towards the river. Also that the spurs from the hills on the western bank slope down gradually towards the gorge, whereas on the eastern bank the rocks form a true scarp, rising almost vertically from the water's edge to a height of some 1,500 feet. Moreover, it is significant that remnants of old river terraces, consisting of well-worn boulders and pebbles, are found on the western slopes to a height of 200 or 300 feet above the present river level, while on the eastern side no recent boulder or pebble beds have been noticed. It seems probable, therefore, that when the river originally took this direction, and was flowing at a much higher level than at present, it took advantage of the great dislocation mentioned above, and began by excavating its course along it, and that, following the general dip of the strata, which is easterly, it has gradually cut back to its present position. It seems not unlikely, too, that when the river first began to flow in this direction, the limestone, which now crowns the scarp on the eastern bank, extended considerably further westwards, and that the valley originated as a limestone gorge.

Influence of faults.

Besides the great overthrust fault mentioned above, there are several other faults of a normal kind which have assisted in determining the course taken by the river. Some of these faults must be of rather recent development, speaking in a geological sense, for they still form conspicuous surface features. Such are the fault scarps along the northern edge of the Hsipaw valley ; a fault running along the Nám-Tu valley for several miles above Tong-ang ferry ; and the great fault scarp running south from Kyaukkyan (D 3), which forms such a conspicuous feature in the landscape as we descend from Maymyo towards Hsum-Hsai. At the point where the Nám-Tu crosses this fault the river is suddenly deflected northwards, forming a narrow loop of several miles in length.

Relation to tributaries.

The frequent sudden changes in the course of the Nám-Tu, and the fact that in almost every case where such a change in direction occurs, a considerable tributary joins the main stream, and the combined waters follow

that of the tributary, seem to suggest that the original drainage of the plateau was more complex than it is at present, and that the courses of these rivers were in former times more independent of each other. The present Nám-Tu seems to be the result of a 'cutting-back' of one river, which has gradually invaded the valleys of the other streams, and turned them into its own channel. This action was no doubt aided by the numerous dislocations affecting the mass of limestone forming the plateau, of which there appear to be two systems, more or less at right angles to each other. If this view is correct, the Nám-Tu, as we find it at present, is as a whole of later date than some of its tributaries. The original courses of these tributaries cannot now be detected, owing to the peculiar nature, to be described below, of the denudation that the limestone of the plateau has undergone.[1]

Sedaw gorge.

The 'cutting back' action of the streams along the edge of the plateau, is well shown in the case of that which issues from the western scarp at Sedaw (**B** 5), where the railway begins the ascent to Maymyo by a series of zig-zags. This gorge extends eastwards parallel to the railway to within a few miles of Maymyo, and for the greater part of its length is of great depth, flanked on either side by perpendicular cliffs of limestone. At the head of the gorge the cliffs draw together, forming a roughly defined cirque, over which the stream plunges in a cataract several hundred feet high. Above this the valley is open, and the stream sluggish. Its source is in the hills north of Maymyo, which lies on the watershed between this stream and the Ke-laung, a tributary of the Nám-Tu. Should the cutting back action at the head of this gorge continue, it will in time capture part of the area drained by the Ke-laung, and if the latter

[1] Perhaps the comparatively recent origin of the course of the Nám-Tu may be the source of a legend current among the Palaungs, a people inhabiting the hilly country of Tawng-peng. According to this, the river was brought into existence by a Chinese Princess named Nang Hkam Lông, possessed of miraculous powers, who visited the Shan States on a raft which she could cause to travel in any direction she pleased, by producing water in front of it. Coming to Loi Hpra, a hill in Tawng-peng, she wished the Sawbwa, or chief of the State, to marry her; but was rejected by him on the plea that 'her bosom indicated old age,' and that he already possessed too many wives. Repulsed by him, she proceeded to Hsipaw, where she was apparently entertained more hospitably, and thence to Ava; and the Nám-Tu marks the course of her journey. The Palaungs believe that if their Sawbwa had not been so ungallant, the river would have run by Loi Hpra, and that their country would not be so mountainous (J. G. Scott, Gazetteer of Upper Burma and the Shan States Part I. Vol. p. 488)

were an important river, considerable changes would be introduced into the river system of the country.

The Salween.

The Salween, forming the eastern boundary of the settled portion of the Northern Shan States,[1] does not, in spite of its size and importance, play much part in the river system of the plateau. It has already been remarked that the Nám-Tu and its eastern tributaries, the Nám-yau, the Nám-má, and the Nám-hka, all rise within a short distance of the Salween, which receives no affluents of much importance in its course through these States. The Nám-pang, the head-waters of which drain the eastern and southern slopes of Loi Ling in South Hsenwi, properly belongs to the Southern Shan States, and enters the Salween a long way to the south, in the State of Keng Hkam.

For a very long distance above the point where the Salween enters the Shan States, indeed as far north as we possess any definite information about the river, it presents the same characters as in British territory. It occupies in Yunnan, where it is known as the Lu Kiang, a long, deep, trough-like valley, closely compressed between the 'Nmai khá, or eastern branch of the Irrawaddy, the Shweli further south, and the Mekhong, and receives no tributaries except mere mountain torrents. Its main catchment area lies well to the north of the sources of the Irrawaddy, indeed it is spoken of as a 'great river' by the French missionaries who were for some years stationed near it about Lat. 28° 20′, or roughly on the parallel of the sources of the Irrawaddy. Prince Henri d'Orléans mentions that, where he crossed the Lu kiang, in about Lat. 26°, the waters of this river are easily distinguished from those of the Lan-tsang kiang, or Mekhong, by reason of the dirty grey colour of the former. This seems to indicate that the Salween rises in a land of glaciers, perhaps somewhere near the Kuen Lun mountains.

Ancient origin of the Salween.

It may be remarked that the Salween, throughout its whole course, flows through palæozoic or Archæan rocks, and, unlike the Irrawaddy or the Himalayan rivers, it does not issue into a broad plain composed of Tertiary or Recent deposits, but maintains the deep, rocky, trough-like character of its valley to within a few miles of the sea coast at Moulmein. It is much more effective,

[1] The country east of the Salween in this latitude is occupied by wild hill tribe known as the Wá (or Lawá), and has not yet been brought under control.

therefore, as a denuding agent than either the Irrawaddy or the Mekhong, for these rivers lose their power of eroding the rocks where they issue into the plains, that is, at a much greater distance higher up their course, relatively speaking, than in the case of the Salween. To this cause may be attributed the great depth of its valley as compared with those of the Mekhong and the tributaries of the Irrawaddy, where these run parallel to it in Yunnan. Captain Gill says that on the road between Bhamo and Tali, where he crossed it in 1877, the bed of the Salween was 1,300 feet lower than that of the Mekhong, and nearly 2,000 feet below that of the Shweli. These considerations lead to the conjecture that the Salween is of far greater age than either of the other rivers, and that the narrowness of its valley is due to the encroachment of these latter upon its original drainage area. It is perhaps only the great depth of its valley which has saved it from being diverted into one or other of the channels on either side of it.

The curious circumstance, that the tributaries of the Salween in the Shan States usually enter the river by a cascade or cataract, mentioned by Sir J. G. Scott (Gazetteer of Upper Burma, Part II, Vol. III, p. 93), may be partly due to a more rapid erosion of its bed than the side streams can keep pace with, but is more probably caused, as Sir George Scott himself suggests, by the enormous rise of the river during the rains, which is on an average between 60 and 70 feet. This rise would pond back the waters of the side streams and cause them to drop their burdens of gravel and boulders at their mouths.

Effect of rock formation on character of streams.

The effect that the geological structure and composition of the rocks has in modifying the forms assumed by the stream valleys may be well studied in the Shan States. On the plateau proper, where limestone is the prevailing rock, denudation proceeds more or less evenly over the whole area, a great deal of it beng subterranean, due to solution of the limestone. The insoluble matter contained in the rock remains on the surface, and forms a thick mantle of red clay, through which the solid rock only appears at intervals. The smaller valleys are broad and shallow, with gently sloping sides, and are usually traversed by sluggish streams, often bordered by morasses. It is only where several streams have united and have sufficient power to cut through the covering of clay, that the rocks beneath are exposed, and then, if the conditions are otherwise favourable, a narrow gorge, bordered by precipitous cliffs of

limestone, and choked with masses of rock fallen from either side, is formed. The deposition of travertine, or calcareous tufa, in all the streams is very rapid. In some cases it raises the level of the stream bed to such an extent, in the shallower valleys, that the water breaks away to one side or the other, and a network of anastomosing channels is formed, resembling that usually associated with deltaic conditions.

The most conspicuous example of this feature is to be seen in the broad valley in which the town of Hsum-Hsai (*Burm.*, Thonzé) is situated, where, on the cart-road and railway, an extraordinary number of culverts and bridges has had to be constructed (*see* Fig. **11**, p. 338). All these streams eventually drain into the single channel of the Hpawng-aw, which flows into the Nám-Tu through a narrow limestone gorge.

Scenery of the plateau.

The scenery of the plateau has a peculiar character of its own: there are no very conspicuous features, except where a fault has depressed one portion of the surface relatively to that of another, and has left a precipitous scarp of limestone, extending in a direct line for many miles, whitened by an accumulation of travertine depending in thick curtains from the cliffs, or where a river has excavated a narrow, picturesque gorge. It is a country of gentle declivities, and rounded interlacing hillocks, covered, as far as the eye can see, after the rainy season, with a dense matting of elephant or *kaing* grass, interspersed in places with low scrub jungle, and in others with park like savannahs of scattered oak trees (Plate 2). It is in fact not unlike parts of the downs of England, or, having regard to the deep red colour of the soil, to the rolling hills of Herefordshire. So well marked is this character of the scenery, that one may be perfectly sure, on finding oneself in such surroundings, that the formation beneath the soil is the Plateau Limestone, even where an outcrop of the solid rock is only to be found after diligent search. The description of the prevailing scenery in the Southern Shan States given by Mr. Fedden[1] shows that it possesses the same features. He also compares it to that of the downs of England or the farm land of Devon.

Non-plateau type of scenery.

The hills that rise in places above the general level of the plateau exhibit an entirely different type of scenery, due to the difference in the character of the rocks. The change from one type of

[1] *Sel. Rec. Gov. Ind.*, XLIX, p. 38.

scenery to the other is always abrupt, and the contrast is exceedingly striking. Within a few hundred yards we proceed from the undulating, somewhat tame, though pretty, scenery of the plateau, into a land of deep, narrow V-shaped valleys, clothed on either hand with dense forest, often of pines (*P. khasya*), which are never found growing naturally on the Plateau Limestone. The crests of the spurs and ridges dividing the valleys are equally narrow, mere knife-edges along which there is often only just room for a mule track. Here the trend of the streams has the closest relation with the geological structure, their direction as a rule following the strike of the folds into which the older Palæozoic and Archæan rocks composing these hills have been thrown; though in some cases they cut directly across the strike. The contrast between the two types of drainage affected by the hill ranges and the plateau may be well seen in the region drained by the Nám-panhsé and its tributaries, which unite at the head of the Gokteik gorge. Here there is a general tendency for the streams to flow in a south-east direction, which is that of the prevailing strike of the older rocks, until they reach the wall of precipitous scarps forming the edge of the plateau, where they collect in the Nám-Tang, which follows this line of cliffs to the head of the gorge, where it joins the Nám-panhsé, also flowing from the north-west along the line of strike. As the train crosses the great viaduct that spans the Gokteik gorge, a very fine view of these contrasting features may be obtained from the railway. Immediately to the north is seen a mass of sharp, inverted-V shaped spurs, densely wooded from base to summit, while on either hand is the undulating surface of the plateau, broken only by the line of stupendous cliffs extending along each side of the gorge.

Western edge of the plateau.

Along the western edge of the plateau, where denudation has partly removed the covering of limestone, and exposed the older Palæozoic rocks beneath, the forms of the valleys combine the two types described above. Where the streams have cut back at right angles to the face of the scarp we have narrow gorges, like that of the Sedaw river described above, bordered by precipitous cliffs and cirques, but where they have removed the covering of limestone, as in the country between the Sedaw river and the Chaung Magyi, or Maddeya River, they flow in deep V-shaped valleys, in a due north and south direction, which is that of the strike of the older rocks in this area.

Red clay of the plateau.

The limestone plateaux of the Shan States differ in one important respect from the ordinary Karst, as such plateaux are usually called, after the well-known district of that name in Carinthia. Instead of the broad expanses of barren rock, with hardly any vegetation except the ferns and mosses that find a habitation in the numerous fissures, typical of a true *Karstgebiete*, we very seldom find, in the Shan States, even a moderately sized area of bare rock visible at the surface. The whole country is buried in an accumulation of red clay, varying in thickness from a foot or two to as much as 30 or 40 feet, or even greater depths. It is only where a spring issues from the limestone, and has washed away the clay as quickly as it is formed, thus preventing its accumulation; or in the beds of the streams; or, again, where the edges of harder strata of lime-stone protrude through the covering, that the solid rock is visible.

Swallow-holes and Kesseltaler.

One phenomenon, however, this region possesses in common with all limestone plateaux. This consists in the occurrence, often over large areas, of depressions in the surface, the drainage in which passes underground. These depressions vary greatly in size, from 'pipes' of a few feet in diameter to 'swallow-holes' (Plate 4) and funnel-shaped 'punch-bowls' (*Brunnenförmige* and *Trichterförmige* Dolinen), of which the latter are by far the most common, and from these to enclosed valleys several miles in length and breadth, traversed by running streams (Kesseltäler) (Plate 3).[1]

Distribution.

The smaller 'punch-bowls' are usually found in greatest number along the crests of limestone scarps, where the water finds an easy outlet on the face of the cliffs, as, for instance, along the edge of the great scarp that runs south from the railway at Kyauk-kyan, near Nawnghkio, to the Nám-Tu. In other cases they have no obvious connection with any scarp, and then are generally of larger dimensions. A large number of depressions of this nature occurs on the wide plateau lying south

[1] There seems to be no good equivalent in English for the German term 'Kesseltal' as applied to a limestone district. The translation 'caldron-' or 'subsidence valley' has been used to denote a phenomenon of a different character (*Quart. Jour. Geol. Soc.*, Vol. LXV, p. 611), a subsidence caused by a single encircling fault; while the English term 'Devil's punch-bowl' applied to the comparatively small hollows of this kind met with on the chalk downs is hardly appropriate in connection with a valley several miles long and wide.

of the Nám-Pawng, between Hsipaw and the Loi Pan range of hills (Plate 5). The drainage from these probably finds its way into the Nám-Pawng.

Origin of swallow-holes and punch-bowls.

The cause of the extraordinary abundance of these depressions seems to lie in the intensely crushed condition of the limestone, which will be referred to in greater detail when this formation is under description (*see below*, p. 93). As the underground solution of the rock proceeds, the whole mass settles down, but more rapidly in those places where the subterranean drainage finds a ready passage; and since the rock is in too shattered a condition to support its own weight, the caverns which we would expect to find in a limestone tract are not formed, but in such places the surface is constantly in a state of subsidence.

'Caverns and natural Bridges.'

The Plateau Limestone in the Northern Shan States is almost entirely in the crushed condition mentioned above, and consequently open caverns are of very rare occurrence. The well-known cavern in the Gokteik gorge, beneath the railway viaduct, is, as I have shown elsewhere,[1] not hollowed out of the solid rock, but is roofed over by a deposit of travertine adhering to the cliffs on either side. There are several of these so-called 'natural bridges' in the Shan States, and in some cases the roof may be of solid rock. This appears to be so with the one on the Nám-sam stream, about three miles north-west of Hsipaw, though here also the rocks at either end of the 'bridge' are greatly obscured by deposits of travertine.

Caverns in Permo-Carboniferous limestone.

The band of Permo-Carboniferous (Productus and Fusulina) limestone that is found at the top of the Plateau Limestone does not seem to have been affected to the same extent by crushing, but is more compact and homogeneous in texture. This limestone usually forms sharp pinnacles or tabular masses with vertical sides, scored with open fissures which give them a characteristic rugged appearance, as seen from a distance, and among these, no doubt, caverns would be found by careful search. These limestones are not, however, greatly developed in the Northern States, but are now the merest remnants of

[1] Note on the Natural Bridge in the Gokteik Gorge, *Records, Geol. Surv. Ind.*, Vol. XXXIII, Pt. I, p. 49.

what must have been a widespread formation. In the Southern States they have not been denuded away to the same extent, and in that part of the country caverns are said to be of common occurrence, though I am not aware that any of them have been explored.[1] Several large caverns occur in the same limestone far to the south, near Moulmein in the Amherst District of Lower Burma, and have been described by more than one writer.[2]

Cavern at Shwe Male.

The cave of Shwe Malé, near the foot of the hills about 8 miles east of the Irrawaddy at Singu, above Mandalay, was visited in 1855 by Sir Henry Yule and Dr. T. Oldham, who have given a very full description of it.[3] This cavern, however, is not in the Plateau limestone but in the crystalline limestone associated with the Archæan rocks of the Ruby Mines District.

Origin of caldron-valleys.

The larger depressions or 'caldron-valleys' (Kesseltäler) are found along the flanks of the ranges to the east of the plateau, where the limestone has been thrown into folds together with the underlying rocks, and has then been denuded from the crests of the anticlinals, so that we have on either side a more or less precipitous scarp of limestone facing the central ridge of the range. The streams flowing down ravines in the latter strike against this wall of limestone, and find their way through it underground, issuing in the deeper valleys beyond. In this way enclosed valleys are excavated, varying in size from mere ravines a few hundred yards across, to a valley like that in which the village of Lukhkai (**I 1**), on the south side of the range east of Lashio, is situated (Plate **3**). This valley is about 4 miles in length by $2\frac{1}{2}$ in breadth, and contains more than one subsidiary depression or 'swallow-hole' within its area (Plate 4). In these valleys the stream that flows through them generally disappears abruptly beneath a vertical wall of limestone into the mouth of a small cave, but in other cases there is no visible outlet, the water soaking through the soil that fills the bottom of the hollow, which becomes a morass during the rainy season.

[1] *See* Middlemiss, in *Gen. Report, Geol. Surv. Ind.*, 1899-1900, pp. 131, 138.

[2] W. Foley, Notes on the Geology, etc., of the Country in the Neighbourhood of Maulamyeng (vulg. Moulmein), *Journ. As. Soc. Beng.*, Vol. V, p. 273, 1836.

S. R. Tickell, Itinerary through the southerly portions of the district of Amherst, Province of Tenasserim, *ibid*, Vol. XXVIII, p. 425, 1859.

[3] A Narrative of the Mission to the Court of Ava in 1855, pp. 177, 330. London, 1858.

Ancient lake basins.

There are no lakes actually existing in the Northern Shan States, but it is probable that the coal-basins of Lashio, etc., were formerly open lakes, which were entirely silted up in late Tertiary times, or were drained by the deepening of the channels of the rivers which flow through them.

From a sketch by the author.

FIG. 1. The Nām Tu at Hsipaw.

CHAPTER III.

GEOLOGICAL FORMATIONS.

Introductory remarks.

In order to present as complete a review as possible of the geological history of the Northern Shan States, certain formations are included in the present description that are not actually found within the borders of the States, the boundaries of which have been drawn for political rather than physical reasons. These formations, the gneisses and associated crystalline rocks of the Ruby Mines District and of Mandalay, constitute the foundation upon which all the succeeding series of strata have been built up, and are therefore included in the list given below. Much still remains to be done in working out the geological relations and structure of these ancient rocks in the field, and of their chemical and microscopic characters in the laboratory; for hitherto they have been examined only in the vicinity of Mogôk, the centre of the ruby mining area. The character of the rocks as seen in the field in this neighbourhood were studied in 1887 by Mr. C. Barrington Brown, who was sent out by the Secretary of State for India for that purpose, and the collections of rock specimens and minerals made by him were submitted to Professor J. W. Judd, who made a searching examination of their petrographic and genetic characters; the result of their labours being a joint paper published in the Philosophical Transactions of the Royal Society,[1] to which further reference will be made below.

My own acquaintance with these crystalline rocks has been confined to one or two rapid traverses across the country occupied by them, and my observations were for the most part made with the view of ascertaining and mapping the boundaries of the area. I was therefore not able to collect sufficient material or data for a complete and critical account of the petrography.

List of formations.

The formations that have been identified in the area surveyed are the following, in descending order:—

[1] The Rubies of Burma and Associated Minerals: their Mode of Occurrence, Origin, and Metamorphoses. A Contribution to the History of Corundum. *Phil. Trans. Roy. Soc. London*, Vol. 187A, p. 151, 1897.

For an abstract of this paper see *Proc. Roy. Soc. London*, Vol. LVII, p. 387.

TABLE I.

List of Formations.

Period.	Local Names and Characters.	Probable Himalayan and Indian equivalents.
Recent	Alluvium. Superficial clays and rainwash. Travertine deposits.	Alluvium. Laterite and Kunkur deposits.
Sub-recent . . .	Old River Terraces. Gem and Gold-bearing Gravels.	Old River Terraces.
Upper Pliocene or Pleistocene.	Silts and sandrock (*fresh-water*), with seams of Brown Coal.	(?) Ossiferous Gravels of Narbada and Godavari.
Lower Tertiary . .	Wanting.	
Cretaceous . . .	Wanting.	
Jurassic . . .	Namyau Series. Red sandstones and shales, with bands of fossiliferous limestone.	Saighan beds of Afghanistan. Upper Gondwanas. Putchum and Chari Groups of Cutch.
Rhætic. . . .	Napeng Shales and Limestone. Fine silty shales, sometimes calcareous, with hard blue limestone at base. Richly fossiliferous.	Para Stage of the Central Himalaya.
Triassic . . .	Wanting.	

Permo-Carboniferous	Upper Plateau Limestone. Limestones with *Fusulina*, *Productus*, etc., occurring only in detached masses, probably the remains of a once widespread formation.	Middle Productus Limestone of the Punjab Salt Range, Central Himalaya, and Urals.
Carboniferous and Devonian.	Lower Plateau Limestone. Finely crystalline dolomites and dolomitic limestones, almost invariably greatly crushed; often a re-consolidated dolomitic breccia. Traces of fossils, minute Foraminifera, fragments of crinoid stems and corals are occasionally found; and in one locality a well preserved Eifelian Fauna.	Upper portion probably equivalent to the Lower Gondwanas. Lower portion certainly in part Middle Devonian. Devonian of Spiti and Chitral.
Upper Silurian	Zebingyi Beds. Black and grey limestones and variegated clays with Graptolites, Tentaculites, Trilobites, etc. Upper Namhsim Beds. Soft marls and limestones with Trilobites, Orthoceras, Brachiopoda, etc. Lower Namhsim Beds. Fine-grained sandstones, with coarse grits and occasionally conglomerates at base, with Trilobites, Brachiopoda, etc.	Upper Silurian of Spiti and Kashmir.
Llandovery	Panghsapyé Graptolite Bed. A thin band of shales, locally carbonaceous, with Graptolites, Trilobites, etc.	

Period.	Local Names and Characters.	Probable Himalayan and Indian equivalents.
Ordovician . . .	Nyaungbaw Beds (*found only to the west of the Gokteik gorge*). Red and blue limestones with Orthoceras, Camarocrinus, and fragments of Crinoids.	Lower Silurian of Niti Pass and Spiti.
	Hwe Mawng Beds (*found only to the east of the Gokteik gorge*). Purple, sometimes calcareous shales, with Trilobites. Perhaps contemporaneous with the upper Naungkanygi Beds.	
	Upper Naungkangyi Beds. Variegated shales with limestone bands. Containing Cystidean plates, Trilobites, etc.	
	Lower Naungkangyi Beds. Sandy limestones and marls with Cystideans, Brachiopoda and Trilobites.	
	Ngwetaung Sandstones. Fine-grained sandstones, with no distinctive fossils.	

TAWNG-PENG SYSTEM (?) CAMBRIAN	Bawdwin Volcanic Series. Rhyolitic tuffs and thin beds of rhyolite and coarse grits. Chaung Magyi Series. Red, purple, and grey quartzites, slaty shales, and felspathic grits, generally showing signs of alteration. No fossils. Mica Schists.	(?) Shillong Series of the Khasi Hills.
ARCHÆAN . . .	Mogôk Gneiss. Scapolite—and garnetiferous biotite — gneisses, with bands of crystalline limestone and lenticular beds of graphite. Rubies and other gems occur in the limestones.	(?) Dharwar System in part.

Nomenclature.

In compiling this list I have thought it advisable not to adopt the classification of the systems proposed by Sir T. Holland in the Summary of Indian Geology published in the latest edition of the Imperial Gazetteer of India (Vol. I, Chap. II).[1]

That classification is intended to apply to the peculiar conditions existing in the Indian Peninsula and the Himalaya; where, as Sir T. Holland explains (*Op. cit.* p. 10), the chief post-Archæan breaks do not correspond to those on which the European nomenclature is founded. Thus the only break of first importance in the sequence of fossiliferous rocks in India, separating the Dravidian from the Aryan Group, took place at about the Permo-Carboniferous stage, when "there was a pronounced revolution in the physical features of the Indian area." In the Shan States, on the contrary, deposition was more or less continuous from lower Ordovician times to the close of the Permo-Carboniferous stage, when a great interruption occurred corresponding to that between the Palæozoic and Mesozoic periods in Europe. Indeed, it was even more pronounced in the area now described, for the whole of the Trias, unless we include the Rhætic with that system, is not represented at all. There seems, therefore, to be no need in the present instance to depart from the nomenclature that has been well established by common usage.

[1] Simla, Government Central Printing Office, 1904.

CHAPTER IV.

ARCHÆAN.

Mogôk Gneiss.

Southern boundary.

The southern boundary of the gneissic area in the Ruby Mines District is fairly well defined by the valley of the Nám-pai (Námpi or Mobi Chaung), which separates the district from the Shan State of Möng Lông (Mainglôn) (**C** 1). For a short portion of its course, to the north-east of the town of Möng Lông, the river flows through the gneiss, but as a rule the latter is confined to the hills on the northern bank, which extend in a succession of parallel ranges from north-east to south-west, the direction of the prevailing strike of the gneiss with its associated bands of limestone. As we proceed northwards, the ranges increase in elevation, their crests rising to a height of 4,000 to 6,000 feet above the sea, until they reach 7,514 feet in Taung Mé (Toungnee, C. B. B.), immediately above Mogôk, (Fig. 2, p. 44), overlooking the broad level plain of the Shweli river. The northward and north-eastward extension of this crystalline rock mass has not been surveyed beyond the limits of the area mapped on the one inch scale, but there is no doubt that it is continuous with the gneisses of the country north of Bhamo,[1] and of south-western Yunnan, where they possess a similar N.E.-S.W. strike.[2]

Western boundary.

To the south of the Ruby Mines District the gneisses occupy the whole of the country between the Nám-Pek or Chaung Magyi river (Mobaychoung, C. B. B.), as the Nám-pai is called in the lower parts of its course, and the Irrawaddy. The Chaung Magyi is at the same time the boundary between the Mandalay District and the Shan States and roughly speaking, between the gneiss and the Lower Palæozoic rocks. In this area the strike is still south-west, but on the western bank of the Irrawaddy it turns due south, and these rocks form the narrow range of hills running parallel to the river which has its

[1] C. L. Griesbach, Geological Sketch of the country north of Bhamo; *Records, Geol. Surv. Ind.*, Vol. XXV. Pt. 3, p. 127.

[2] L. v Loczy, in Gral Bela Szechenyi's Reise in Ostasien, Vol. I, p. 776.

termination at Sagaing, opposite Mandalay. The change of strike takes place near Wabyudaung (Wapudoung, C. B. B.) (**A** 1) about 13 miles to the east of the Irrawaddy, and is perhaps the cause, through torsion of the strata, of the extraordinary broadening of the bands of limestone in that neighbourhood, as shown in the map attached to Mr. Barrington Brown's paper. On the eastern bank the Palæozoic rocks of the Shan plateau come right down to the plains of the Irrawaddy, and the Archæan gneisses are found to occur only in a few outlying hills rising abruptly from the alluvium, including the Sagyin hills, mainly composed of the crystalline limestone, which is largely quarried as statuary marble,[1] and Mandalay Hill, which consists of the same limestone, traversed by veins of granite.

The gneisses appear again at the foot of the plateau scarp at Kyauksé, where there are large marble quarries, 25 miles south of Mandalay, and beyond this they form a continuous band, from 12 miles upwards in width, along the edge of the Southern Shan plateau, extending to the sea near Moulmein.[2]

Petrography.

The following account of the gneisses and associated rocks and minerals of the Ruby Mines area is taken from the abstract of the paper by Mr. C. Barrington Brown and Professor J. W. Judd, referred to above (p. 27) :—

"The general mass of gneissic rocks composing the mountainous district in which the ruby localities are situated are of intermediate chemical composition, and consist of biotite-gneisses, biotite-granulites, and, more rarely, biotite-schists—rocks in which hornblende is rare or altogether absent, but which, on the other hand, are often remarkably rich in garnets. Neither corundum or spinel have been certainly detected in these rocks.

"Interfoliated with these ordinary gneissic rocks, which form the great mass of the mountains, we find rocks of much more acid composition, including very coarse pegmatites and graphic granites, aplites and granulites (leptynite or Weiss-stein), gronular quartzites, and orthoclase-epidote rocks. The orthoclase of these rocks frequently contains inclusions of fibrolite and other minerals; it often exhibits the 'murchisonite' modification and partings, and is not unfrequently converted into 'moonstone'; still more complete alterations of the orthoclase into epidote, muscovite, and kaolin being by no means uncommon. In the rubellite district of Nyoungouk these acid rocks contain pink and blue tourmaline (rubellite and indicolite), often beautifully zoned, and it is probably from rocks of this class that the fine gem rubellites are derived.

[1] Dr. T. Oldham, Appendix to Yule's Mission to Ava, 1858, p. 326.
C. L. Griesbach, Notes from the Geological Survey of India; *Records, Geol. Surv. Ind.*, Vol. XXIX, pp. 9, 60.
[2] C. S. Middlemiss, in *General Rep. Geol. Surv. Ind.*, 1899-1900, p. 128

"Of still greater interest are certain other subordinate rocks of basic and sometimes ultra-basic composition. These include the remarkable pyroxene gneisses and pyroxene-granulites, which have in recent years been described as occurring in so many widely-scattered regions—such as Ceylon, Southern India, Central and Southern Europe, Norway and Sweden, Brittany, Spain, Algeria, Eastern, Western, and Southern Africa, the United States and Canada, Brazil, and New Caledonia. In these rocks the felspars are for the most part basic ones, near to anorthite; the crystals almost always exhibit the phenomenon described by French petrographers as 'quartz of corrosion', and the partial or complete transformation of these felspars into scapolite ('werneritisation') can frequently be traced. The ferro-magnesian silicates are represented by many varieties of augite (sahlite, diopside, and ægerine), of enstatite (bronzite and hypersthene), and more rarely of hornblende. Garnets are a frequent and abundant constituent in many of these rocks, which, in their accessory minerals and their structures often exhibit many features of striking interest. By the gradual disappearance of the felspars from these rocks, they pass into remarkable varieties of pyroxenites and amphibolites. The chief varieties of these rocks, which are now described from Burma, are the following:—Augite-gneiss (with sahlite, green diopside, etc.), augite-granulites (very rich in garnet), enstatite-gneiss (with bronzite or hypersthene), enstatite-granulites (rich in garnet) scapolite-gneisses, scapolite-granulites, pyroxenites and amphibolites of many varieties, and lapis-lazuli (lazurite-diopside-epidote rock). Many of these rocks contain crystals of calcite scattered through them.

"It is with these basic rocks, and more especially with the ultra-basic types last mentioned, that the remarkable crystalline limestones that contain the rubies and spinels are most intimately associated; indeed the passage of rocks consisting of various silicates with a few calcite crystals into masses principally composed of calcite, but with the silicate minerals and oxides dispersed through them, is of the most insensible kind. Some of the ruby-bearing limestones are highly micaceous ('cipollinos'); others are 'calciphyres,' in some of which the individual calcite crystals attain enormous dimensions. With the rubies and spinels are found a great number of oxides and silicates both original and secondary, with much graphite and pyrrhotite."

* * * * * * * *

"The association of minerals in the remarkable crystalline limestones of Burma is worthy of the most careful consideration. Corundum—in its various forms of ruby, sapphire, white sapphire, oriental amethyst, orintal topaz, etc.—is found associated with red, purple, brown, black and other spinels, the relative proportions of the minerals composed of aluminium oxide and of magnesium aluminate being very variable. The other minerals present in the crystalline limestones are zircon (rare); garnets (abundant in some places); a remarkable blue apatite; felspars, of many species and varieties (including murchisonite, moonstone, sunstone, etc.), and in every stage of alteration; quartz (in many varieties, and exhibiting some remarkable peculiarities of crystallisation); micas (phlogopite, fuchsite, with muscovite and other secondary and so-called hydro-micas); hornblende and arfvedsonite; augite (sahlite, diopside, and ægerine); enstatite (bronzite and hypersthene); wollastonite;

lapis-lazuli; fibrolite; scapolite; with graphite and pyrrhotite. In addition to muscovite and other secondary micas, we find the following alteration products:—Diaspore, margarite and other clintonites, chlorites, vermiculites, and carbonates.

"It is a noteworthy circumstance that none of the silicates combined with fluorine and boron compounds—such as topaz, tourmaline, chondrodite and humite, axinite, or datholite—have been certainly detected in these limestones.[1] Beryl (aquamarine) and danburite have been said to occur in the ruby earths, but there is reason for doubting the correctness of the statement. The limestone which, in the association of minerals found in it, most closely resembles the rock of Burma, is the remarkable white limestone of Orange County, N. Y., and Sussex County, N. J., but in the American rock the corundum and spinels are associated with tourmalines and chondrodites.

"In considering the question of the *origin* of the corundums and spinels of Burma, there are several very important facts to be borne in mind. The gems, when found *in situ*, always appear to occur in the limestone, and this limestone is of a very remarkable character. There are no facts which point to the conclusion that the limestone was originally of organic origin, but many circumstances suggest that it may have been formed by purely chemical processes going on at great depths within the earth's crust. The highly-crystalline calcareous rock, besides containing so many silicates and oxides, associated is in the most intimate manner with pyroxene-gneisses and granulites containing anorthite, and with various pyroxenites and amphibolites. The lime felspars and lime-soda felspars of these rocks show the greatest tendency to undergo change—passing into scapolites by the process known as 'werneritisation,' and eventually giving rise to the separation of calcium carbonate and hydrated aluminium silicates. That from the last mentioned salts the hydrated oxides of aluminium (diaspore, gibbsite, bauxite, etc.) may be separated has been shown by the studies of Liebrich and others, while the conversion of these substances into the anhydrous aluminium oxide has been shown to take place by H. St. Claire Deville, Stanislas Meunier, and others.

"Of still greater interest than the question of the origin of the corundums and spinels are the problems connected with the remarkable changes that these minerals undergo in deep-seated rock masses. The rubies of Burma, when found *in situ* in the limestones, are usually seen to be enveloped in a mass of materials produced by the alteration of their superficial portions. Nearest to the unaltered gem is a zone of diaspore—the hydrated aluminium oxide—and this is found to pass insensibly into various hydrous aluminous silicates—margarites and other clintonites, vermiculites, muscovites, kaolinites, etc. While, in some instances, the corrosion of the rubies appears to have gone on in a seemingly irregular manner, in the majority of cases a very definite mode of metamorphosis may be detected by the study of the various examples. There are evidently certain planes of 'chemical weakness' (analogous to the cleavage planes, gliding planes, and other direction of physical

[1] In the crystalline limestone of the Manwe-Naniazeik ruby tract in the Kachin Hills chondrodite and tourmaline are both found, according to Dr. Bleeck. (Rubies in the Kachin Hills; *Records, Geol. Surv. Ind.*, Vol. XXXVI, Pt. 3, p. 167).

weakness) along which decomposition goes on most readily. The principal of these solution planes is the basal plane, and parallel to it we find the gems eaten away in a series of step-like surfaces. Other less pronounced planes of chemical weakness exist parallel to the prism faces. Unaltered corundum is, like quartz, destitute of true cleavage, and breaks with a perfectly conchoidal fracture. If, however, gliding planes and lamellar twinning be developed in corundum (like those so easily produced in the same way in calcite), parallel to the fundamental rhombohedron of the crystals, then these gliding planes become 'solution planes,' along which chemical action takes place most readily. Along the primary or secondary solution planes, hydration of the aluminium oxide takes place, and disapore is formed, as shown by Lawrence Smith and Genth, and this unstable mineral enters into combination with silica and other oxides present to give rise to the numerous pseudomorphs of corundum, which are so well known to mineralogists."

In the paper published *in extenso* in the *Philosophical Transactions*, Professor Judd gives further details regarding the supposed origin of the limestone from the alteration of the unstable scapolite contained in the basic gneisses,[1] and it must be said that, given no possibility of the mass of the limestone having been of sedimentary origin, the theory put forward seems to be quite convincing. But, diffident as I feel in criticising the conclusions of so high an authority as Professor Judd, I must say that the result of my own observations in the field has led me to entertain considerable doubt as to the adequacy of the explanation given to account for the formation of such enormous masses of practically pure calcite. The manner in which these bands of limestone occur in the field is so much in agreement with their having been originally components of a sedimentary series, associated along a particular zone with rocks of igneous origin (whether intrusive or contemporary cannot now be determined, owing to the intense pressure and dislocation to which the whole complex has been subjected), that it would require, to my mind, the very clearest evidence to show that they could never have been sedimentary rocks. As Mr. Barrington Brown has shown,[2] they occur only along a particular zone in the gneisses, and within this zone they appear to have consisted of several continuous bands, which have been broken up and drawn out by earth stresses in such a manner that they now present the appearance of a number of greatly elongated, lenticular masses, each individual band dying out completely at intervals, but continued *en echelon* across the country; much as veins of

Loc. cit., p. 214.
Loc. cit., p. 156 *seq.*

calcite or quartz are seen to have been drawn out into lenticular 'eyes' in a rock mass that has been subjected to great pressure and torsion. The presence of the narrow bands of gneiss in the limestone, described by Mr. Barrington Brown, [1] seems also to me to militate strongly against the acceptance of Professor Judd's theory, for it is not easy to see how these bands could have escaped the alteration which, according to that theory, has entirely destroyed the gneiss on both sides of them. It is true that Professor Judd does not assert that the calcite has been entirely crystallised *in situ*, for he adds to his explanation of the process by which the original felspars of the basic gneisses have been transformed into scapolite, by 'Werneritisation,' and from that to calcite by ordinary decomposition, the words[2] :—

"If this be the case, it is, of course, necessary to suppose that the calcium carbonate has been often transported to new localities in solution, while the basic aluminium and other silicates have in some cases been broken up, so as to give rise to the formation of corundum, spinel, and the various other minerals occurring in the limestone or in the rocks so closely associated with it."

If such a transference of the carbonate of lime has taken place, and if this re-distribution of that mineral is supposed to account for the thick bands of practically pure calcite now to be seen, the theory would seem to require that the anhydrous alumina should have been transported in the same way by solution and re-deposition. Otherwise the gems would not now be found in the body of the limestone. Surely these minerals would have been left behind, and should now be found in the gneiss bordering on the limestone, where, it is quite certain, they do not occur at all.

Crystalline limestones of Ceylon.

The cipolins of Ceylon, which are also associated with pyroxenic gneisses, have been described by M. Al. Lacroix,[3] but no complete account is given of the genesis of the limestones. M. Lacroix remarks (*Records*, p. 195) that at Cornigal (Kornegalle) elliptical masses occur in the cipolins made up of a mixture of different minerals and presenting a composition closely comparable to that of the pyroxenic gneisses of the same region, and infers that they have been derived from the cipolins. In this case

[1] *Loc. cit.*, p. 175.
[2] *Loc. cit.*, p. 215.
[3] Gneissose rocks of Salem and Ceylon; *Bull. de la Soc. Franc. de Mineralogie*, XII (1889); translated by Mr. F. R. Mallet in *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 3 (1891).

the process, according to M. Lacroix, would be the reverse of that which is supposed by Professor Judd to have taken place in the formation of the Ruby Mines limestone.

Crystalline limestones in the Dharwar system.

An important contribution to the discussion of the origin of such crystalline limestones has been furnished by Dr. L. L. Fermor.[1] In this paper the genesis of the limestones is attributed to causes similar to those put forward by Professor Judd, that is, they are considered to have been formed by the alteration of pre-existing rocks containing lime and magnesia silicates, the process necessitating the introduction from without of carbon dioxide dissolved in heated waters. Dr. Fermor was led to this conclusion by the similarity between the mineral constituents of the calciphyres and of the quartz-pyroxene gneisses of the district, and though he does not go so far as to say that the limestones have been derived directly from the gneisses by chemical alteration, he thinks that they may have originally possessed practically the same composition. Since this paper was written, however, Dr. Fermor has considerably modified his opinion, and in order to account for the presence of carbon dioxide in sufficient quantities to effect the change into crystalline limestone, he supposes that in the first instance the Dharwar rocks of Chhindwara consisted of sediments, partly calcareous; that these were converted, under conditions of high temperature and pressure, into calcareous gneisses, with the expulsion of large quantities of carbon dioxide; that the gas so expelled was kept in solution at a high temperature and pressure in the waters impregnating the rocks; and finally, that as soon as these conditions abated, the waters, charged with alkalies in addition to the carbon dioxide, began to attack the recently formed gneisses, and to re-convert them into limestones. Dr. Fermor's ultimate conclusion is, therefore, that whatever may have been the changes through which the crystalline limestones of Chhindwara have passed, they may have been in the first instance sedimentary deposits; whether these were formed by chemical deposition, or whether the carbonate of lime was accumulated by living organisms, is another question, but it is one that has no particular bearing on the present argument.

[1] Notes on the Petrology, etc., of Chhindwara District, Central Provinces; *Records. Geol. Surv. Ind.*, Vol. XXXIII, Pt. 3, p. 150.

Presence of graphite.

The presence of graphite in the limestone might be considered as a strong argument in favour of attributing an organic origin to the latter, but since it has been discovered that graphite occurs, apparently as an original constituent, in some igneous rocks,[1] and is not uncommonly to be found in Archæan gneisses and schists, it is not possible to rely on its occurrence in these limestones as a proof of their having been organically formed in the first instance, without convincing evidence of some other kind, which is not forthcoming. Whether the carbon was originally provided by organic matter or not, it is certain that it has been in a state of fusion, for according to Holland,[2] the graphite in the limestone of Sagyin, which is identical with that of the Ruby Mines, when heated after treatment with fuming nitric acid, exhibits the phenomenon known as 'sprouting,' and this property has been shown by Moissan[3] to be confined to graphite that has crystallised from fusion.

Alternative hypothesis.

It is, however, not at all necessary to call in the aid of organisms to account for the formation of limestone strata, and there is nothing impossible in the inclusion in a complex of sedimentary and igneous rocks of Archæan age, previous to the existence in any form of living matter on the earth, of bands of limestone. If, then, all these rocks were subjected together to the action of intense metamorphic forces, it is conceivable that the mineralogical changes that have taken place have operated in a direction opposite to that supposed by Professor Judd, that is to say, that the calcite, either in a state of fusion or one akin to it, has invaded the surrounding gneisses, and has converted the felspars into scapolites, the excess becoming crystallised among the original constituents of the rock as calcite. That the latter mineral may be fused, and invade the surrounding rocks without decomposition, under certain conditions, has been

[1] J. Walther, On Veins of Graphite in decomposed Gneiss (Laterite) in Ceylon; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 1, p. 42: Al. Lacroix, Gneissose Rocks of Salem and Ceylon; *ibid*, Pt. 3, p. 155: H. Moissan, Étude du Graphite extrait d'une Pegmatite; *Comptes Rendus*, Vol. CXXI, p. 538: F. D. Adams, Geology of a portion of the Laurentian Area; *Ann. Report, Geol. Surv. Canada*, N. S., Vol. VIII, J, p. 36: T. H. Holland, Charnockite Series; *Memoirs, Geol. Surv. Ind.*, Vol. XXVIII, Pt. 2, p. 152; Sivamalai Series, *ibid*, Vol. XXX, Pt. 3, p. 172: T. L. Walker, Geology of Kalahandi State; *ibid*, Vol. XXXIII, Pt. 3, p. 14: F. Cirkel, Graphite, its Properties, Occurrence, Refining, and Uses; Ottawa (1907).

[2] *Op. cit., Memoirs, Geol. Surv. Ind.*, XXX, Pt. 3, p. 175.

[3] *Loc. cit.*, p. 540.

shown in the case of the nepheline syenites of Alnö by Högbom,[1] and in that of the elæolite-syenites of Sivamalai by Holland,[2] and it is even known to occur, as a primary constituent, in granite.[3]

Organic origin of graphite.

There is one circumstance in connection with the presence of graphite in the Ruby Mines limestone which tends to indicate that the carbon may be of organic origin, namely, that this mineral has not been found in the gneisses with which the limestone is intercalated, but is confined to the latter rock. The deposits of graphite near Wabyudaung (Wapudoung, C. B. B.), which have been opened out and worked to a small extent by the Ruby Mines Company, occur along the line of contact between the gneiss and limestone, but it is not disseminated through the gneiss. In Canada, however, where the association of graphite with crystalline limestone and gneiss seems to be very similar to that we are dealing with, the graphite is disseminated through both rocks. But F. Cirkel, in his monograph on graphite,[4] is of opinion that the graphite of limestones is derived from carbon originally present in the rock, probably of organic origin, and on the other hand, following Weinschenk,[5] that the source of the graphite veins in the gneiss must be sought deep in the earth, where it is supposed to have been deposited from carbon monoxide and compounds of the cyanogen group.

Crystalline limestones of Naniazeik.

Further light has been thrown upon the question of the origin of the crystalline limestones of Upper Burma by the researches of Dr. A. W. G. Bleeck, of Münich, who has examined the rocks of the Manwe-Naniazeik ruby tract in the Kachin Hills.[6] Describing the limestones, he says :—

"Every single specimen possesses the peculiarity of giving off an evil smell when struck with the hammer. This smell originates from organic matter, probably skatole."

This observation would equally well apply to the limestone of the Mogôk Ruby Mines, indeed so powerful is the odour that on a hot day it is not necessary to strike the rock with a hammer in

[1] A. G. Högbom, Nepheline-syenite of Alnö ; *Geol. Fören. Stockholm Förhand.* XVII, 2 and 3, pp. 100 and 214. Abstract in *Mineral Mag.*, Vol. XI (1895), p. 250.

[2] T. H. Holland, *op. cit.*, *Memoirs, Geol. Surv. Ind.*, Vol. XXX, Pt. 3, p. 197.

[3] E. Rimann, Ueber calcitführenden Granit in Riesengebirge, *Centralb. für. Min. Geol. u. Pal.* Jahrg., 1907, p. 203.

[4] Graphite, its Properties, Occurrence, Refining and Uses, Ottawa (1907).

[5] E. Weinschenk, Bildung des Graphites ; *Zeitschr. f. Prakt. Geol.*, 1903, p. 16.

[6] On Rubies in the Kachin Hills ; *Records, Geol. Surv. Ind.*, Vol. XXXVI, Pt. 3, p. 164.

order to render it perceptible, but on entering a quarry in the limestone it is almost everpowering, even at a distance of several feet from the rock face. Even this evidence, however, is not conclusive in favour of the limestone having been organically formed, that is, in the sense of being built up by living organisms, unless it can be proved that the odour is really due to skatole. To my mind the smell appears to possess a more sulphurous character than one due to any organic compound, and to be derived from the decomposition of the sulphide of iron (pyrrhotite) with which the limestone is impregnated.

Accessory minerals in Naniazeik limestone.

Dr. Bleeck also draws attention to the presence of chondrodite, forsterite, and garnet in the limestone of Naniazeik, minerals that were not found in that of Mogôk by Professor Judd, and to the comparative rarity of corundum in the former, and suggests that the difference is due to local variation in the character of the agents that have effected the metamorphism of the rocks. In the Naniazeik area contact metamorphism, due to the intrusion of massive dykes of granite, has predominated, whereas in the Ruby Mines district pressure metamorphism has played the more important rôle, with the result that in the latter area corundum is more abundant, and the typical minerals due to contact metamorphism, such as forsterite, chondrodite, and garnet, are either rarely found or are absent.

Supposed conglomerate at Sagyin.

In the Annual Report of the Geological Survey of India for 1895,[1] Mr. Griesbach alludes to an examination by Mr. Hayden of the ruby-bearing limestone of the Sagyin Hills, in the Irrawaddy valley north of Mandalay, and says :—

"One of the most interesting facts established by Mr. Hayden is that the limestone rests on the schists and gneiss, the junction being marked by the presence of a conglomerate associated with a limestone breccia, thus proving without doubt that this coarsely crystalline limestone is of sedimentary origin."

And again[2] :—

"The crystalline limestone, in which such minerals as ruby, spinel, rubellite and schorl occur, is found to be separated from the gneisses by a conglomerate composed of blocks of limestone, gneiss and quartzite."

[1] *Records, Geol. Surv. Ind.*, Vol. XXIX, Pt. 1, p. 9.
[2] *Ibid.* p. 60.

If this observation were confirmed, it would of course settle the question of the sedimentary origin of the limestone, and considerably strengthen the argument in favour of the organic origin of the graphite ; but I am informed by Mr. Hayden, whose report on this tract has not been published, that he is not convinced that the conglomerate was actually *in situ* at the base of the limestone, and that what he saw was probably a superficial boulder deposit, cemented by calcareous matter ; and as I know, from my own experience, that such superficial deposits of what is to all appearance a hard and ancient conglomerate are not uncommonly to be met with in the stream beds, especially along the western edge of the Shan plateau ; and that, in some cases, the detection of their real character, and of the fact that they are not interbedded with the older rocks, is not easy, I think it would be unwise to lay too much stress upon the observation quoted by Mr. Griesbach, without further investigation of the facts.

Age of the gneiss and crystalline limestones.

Regarding the age of these ancient crystalline rocks, it seems to me that we may be dealing with two systems belonging to very different periods. The similarity between the complex of crystalline limestones, pyroxene and scapolite gneisses, and granulites of the Ruby Mines with some of the developments of the Dharwar system of the Indian Peninsula is very marked. I have already alluded to Dr. Fermor's account of the crystalline limestones occurring in the Dharwars of the Chhindwara district in the Central Provinces,[1] and a perusal of his paper will show that the characters and relations of the rocks in the two areas are almost identical. In both districts we have a series of crystalline limestones closely associated with quartz pyroxene gneisses and calciphyres, forming lenticular bands imbedded in biotite gneisses, which latter, in Chhindwara, Dr. Fermor looks upon as being the most ancient rocks of the area. The parallel is completed by the fact that in both areas the rocks are intersected in every direction by veins of graphic granite or pegmatite. It seems probable, therefore, that the biotite gneisses should be referred to one of the lower divisions of the Archæan group, while the limestones and associated pyroxene gneisses, etc., may be considered to belong to the Huronian system, with which the Dharwars of the Indian peninsula

[1] *Records, Geol. Surv. Ind.*, Vol. XXXIII, Pt. 3, p. 159.

are correlated. For the present, however, and until the relations of these crystalline rocks may be more thoroughly investigated in the field, I consider it advisable to place them in a single group.

From a sketch by the author.

FIG. 2. The Ruby Mines, Mogôk. Taung Mé in the background.

CHAPTER V.

TAWNG-PENG SYSTEM.

Distribution.

Between the gneiss of the Ruby Mines District and the fossiliferous rocks of the Shan Plateau a broad area of broken, hilly country intervenes, in which very little level ground is to be met with. It forms a maze of deep, V-shaped valleys, separated from one another by steep, knife-edged ridges and spurs, clothed from base to summit in dense vegetation. So precipitous are the lower slopes of the glens that it is often impossible to find a way along the banks of the streams, and the rocks are as a rule accessible only where the narrow paths between the villages, perched on the ridges above, cross the valleys.

Name of system.

Except for a narrow zone along the margin of the plateau, the whole of this broken country is occupied by rocks which so far have not yielded fossils, and as they appear to form a well defined group of strata, and to be separated by a distinct stratigraphical break from the succeeding formations, the name of the Tawng-peng System is now bestowed upon them, since the sub-State of that name, noted for its production of the pickled tea, or 'letpet,' so freely indulged in by the Burmese, is almost entirely composed of these rocks. The whole of this hilly tract is inhabited by the Palaungs or Rumai, a race of hill men differing in customs and language from the Shans, but devout Buddhists, and of very peaceable disposition. According to Sir J. G. Scott [1] they may be allied either to the Karens of Lower Burma or to the Wá tribes, who are found on the other side of the Salween, but they also show some affinity in their customs with the hill tribes of Assam.

Sub-divisions.

The rocks of the Tawng-peng System are divided into three series, which have been named, in descending order :—

Bawdwin Volcanic Series.

Chaung-Magyi Series.

Mica Schists of Möng Lông.

Of these the middle series is the most important from a stratigraphical point of view, since it occupies a far greater area than either of the others, but in an economical sense the rocks composing it are not of much value, though a small quantity of gold

[1] Gazetteer of Upper Burma; Part I, Vol. I, p. 486.

is obtainable from many of the streams that drain them. In this respect the rocks of the Bawdwin series are the most important, for they contain the only really promising deposits of metallic ores that have yet been discovered in the Shan States.

Mica Schists of Mŏng Lông.

Area occupied.

To the south of the gneissic area in the Ruby Mines District a broad bolt of mica schists is found occupying the wide valley of the Nám-pai, in which the town of Mŏng Lông, the capital of the sub-State of that name, is situated, and the spurs of the range of hills to the south of it. The strike of these beds shows more irregularity in direction than that of the gneiss, probably due to the intrusion of thick dykes and bosses of granite along the boundary, but in general it is nearly east and west. The western termination of the band is somewhat uncertain, owing to the almost inaccessible nature of the middle portion of the Nám-pai valley, where it meets the south-westerly extension of the Mogôk gneiss; but as the lower portion of this valley, from Setsigôn (B 2) to Ze-haung, coincides with a N.-S. fault, it is probable that the mica schists are cut off by an extension of this fault to the north. The southern boundary of the mica schists is very indefinite, and the line drawn on the map must be considered as only roughly approximate. On the hill slopes it is exceedingly difficult to find any outcrop of the schists, for they are easily weathered, and all that can be seen in the few exposures visible along the paths are patches of micaceous clay in which the original foliation planes are marked by splashes and lines of bright scarlet, resulting from the oxidation of the iron in the rock. And since the rocks of the next succeeding formation weather in much the same way, though not, as a rule, with the same brilliant colours, it is not at all easy to decide where to draw the line between them. Indeed it is not unlikely that there is a gradual passage from one to the other formation, and that the higher degree of alteration of the mica schist is due to contact metamorphism, induced by the intrusive granite alluded to above. For it has been noticed elsewhere that when dykes and bosses of granite are intruded among the slates of the Chaung-Magyi series, they have a tendency to become schistose.

Character.

The rock is an ordinary biotite schist, composed mainly of granular quartz and biotite, the latter in large quantity in lath-shaped crystals, arranged parallel to the

foliation planes, and a little plagioclase felspar: minute crystals of apatite and some schorl (?) are present as accessory constituents.

Quartz-veins.

The mica schists are everywhere traversed by veins of milk-white quartz, of all dimensions up to a width of several feet, ramifying in all directions through the country rock. These veins are perhaps more numerous near the junction of the schists with the granite, but they are not confined to any particular zone, and on the spurs of the hills they frequently form the only visible outcrops, generally standing out as prominent knolls on the ridges.

Intrusive granite.

Along the boundary between the gneisses and mica schists several strong dykes of intrusive granite occur. They are well seen on the cart road from Mogôk to Möng Lông between the villages of Yaunggwin (Nyaunggôn) and Legyi (Lauzee, C.B.B.), and extend for many miles to the east and west of the road. The rock is a coarsely crystalline granite, consisting mainly of orthoclase felspar with some interstitial quartz and a good deal of tourmaline. Fibrolite, apatite and garnet are present as accessory constituents. Extensive excavations for tourmaline (rubellite) have been made in the rain-wash derived from these granites covering the lower slopes of the hills in the neighbourhood of Na-yuk (Nyaungdauk, Nyoungouk, C.B.B.), about 11 miles to the south-east of Mogôk.[1]

Chaung-Magyi Series.

Lithological characters.

It has been stated above that the boundary between the mica schists and the Chaung-Magyi series is somewhat indefinite, and that there is reason for supposing that there is a passage from the more highly foliated type of rock to one which shows little or even no signs of alteration. As we proceed southwards from the Nám-pai valley towards the Shan plateau, the well foliated mica schists give place to a series of quartzites, generally of a red or brown colour, occasionally containing a little felspar, when they may be called greywackes, slaty shales, generally dark blue or black in colour, and sandstones. No conglomerates whatever have been observed throughout the whole series, and there are no signs of any stratigraphical break. All the beds are either sandy

[1] C. Barrington Brown and J. W. Judd, *Phil. Trans. Roy. Soc.*, Vol. 187 A, (1897), p. 185.

or argillaceous, and lime is not present in any form: this is the more remarkable, since all the succeeding formations are, to a greater or less extent, of a calcareous nature.

Paucity of outcrops.

Except in the beds of the streams, and along the cuttings of the new roads that have been made through the hills, outcrops of the rocks are not often met with, owing to the thickness of the 'cover' of clay and soil in which the hill slopes are buried, and, moreover, they are so thickly clothed with vegetation that landslips very seldom occur. For this reason anything like a continuous section is not to be seen, so that it has been found impossible to trace the different varieties of rock from one locality to another. The strike of the beds also is by no means constant; for though it sometimes remains the same for considerable distances, it is subject to abrupt changes in direction, and this adds to the difficulty of following out any particular band of rock. The strata are also greatly dislocated by faults, which for the same reasons cannot be followed up continuously for any distance, and these add greatly to the complexity of the structure. It would, of course, be possible to work out the stratigraphy in much greater detail than has been done, in spite of the scarcity of outcrops and other difficulties, but it would entail an enormous amount of labour, and since the series possess very little economic value, there would be no object in spending time and labour upon it.

Mode of weathering.

Another circumstance that enhances the difficulty of dealing with the relations of the different beds of this series to each other and to the overlying formations is their mode of weathering. Wherever they have been exposed to the atmosphere for any length of time they become rotten and decomposed, and are not easily to be distinguished from ordinary sandstones and shales, such as are common among the succeeding formations.

Indications of alteration.

In fresh outcrops, however, either in the streams or road cuttings, it is often possible to discover some signs of alteration in the older rocks. The quartzites, under the microscope, exhibit in some specimens a secondary growth of the quartz grains, filling up the interstices between them; and the slates are usually spotted with minute stains of iron oxide, probably resulting from the decomposition of granules of iron pyrites, drawn out in the direction of the shear

planes of the rock. The high angles of dip usually presented by these older rocks may also be taken as a guide in mapping them, especially in the neighbourhood of the boundary with the Námhsim sandstones, for which they are most likely to be mistaken, for the latter rocks as a rule rest at low angles upon their upturned edges.

Distribution, Western boundary.

The rocks of the Chaung-Magyi series formed a continuous floor upon which the succeeding fossiliferous formations were deposited, and wherever the latter have been removed by denudation to a sufficient depth, these older rocks are exposed beneath them. Along the western edge of the plateau they occupy a narrow zone below the precipitous scarps of limestone overlooking the plains of the Irrawaddy, extending due south along the left bank of the Chaung-Magyi or Maddeya river,—from which the name of the series is derived,—to the point where, leaving the hills at Zehaung, it turns west to the Irrawaddy; and beyond this to within a short distance of the head of the Kyetmaôk stream, above the village of Taunggaung (**B** 4). The western boundary of this zone is marked by a fault, bringing the Chaung-Magyi rocks against the Archæan gneiss to the north of Zehaung, and against the Plateau Limestone and underlying Palæozoic rocks to the south of that place. Throughout this zone the strike of the quartzites and slates is N.—S., parallel to that of the gneisses on the west bank of the Irrawaddy.

Southern and Eastern boundary.

The inner boundary of this zone is more irregular, the actual location of the line of junction depending on the depth to which the great western scarp of the plateau has been cut back, and on the relations between the dip of the rocks and the contours of the hill slopes. Towards the north the elevation of the boundary line above the plain gradually increases, until at a point somewhat to the south-east of the sudden bend of the Nám-pai from west to south (at the peak marked Hpataunggyi, 3,664 feet on the map, Fig. 3, p. 62), the overlying rocks disappear, and the boundary sweeps round to the south-east in the direction of the head of the Gokteik gorge. At the same time the strike of the rocks also changes in direction, and becomes N.W.—S.E., or almost at right angles to the prevailing strike of the gneisses. The rocks in this area form a succession of straight ridges, coinciding in direction with that of the strike, and separated by streams flowing either to the north-west, into the Nám-pai,

or to the south-east, into the Nám-panhsé and the Nám-Tu. Among the hills to the north of the Gokteik gorge the strike becomes very irregular for a space, and the rocks are greatly contorted, but further to the eastward it again becomes regular, and is at right angles to its former direction, or from north-east to south-west. The contrast between the lofty ranges of hills formed by these rocks and the more level limestone plateau is well seen from the railway between the Gokteik gorge and Hsipaw, the boundary running in a north-easterly direction at no great distance from the line, to within a few miles of the Nám-Tu, where the older rocks disappear beneath the fossiliferous Palæozoics. The eastern boundary is very irregular, and deeply indented, on account of the immense amount of erosion that has taken place along it.

The 'Eastern Ranges.'

The Chaung-Magyi rocks appear again along the eastern margin of the plateau, among the hilly ranges between it and the Salween, forming large inliers among the younger rocks, wherever the latter have been removed by denudation. The most northerly of these inliers shown on the map is in the range that extends eastwards from Lashio towards the Salween (hereinafter referred to as the Loi Len range), and forms the divide between the upper valleys of the Nám-yau and the Nám-pawng. The slates and quartzites appear from beneath the lower Palæozoic rocks at the foot of the range, immediately to the north of Mán-Sé (**H** 1) in the Námma coal-field, and widen out rapidly eastwards, forming the whole of the southern slopes for a distance of about 18 miles, beyond which they are covered up by overlying limestones (*see* Section 1, Plate 24). Along the foot of the range they are cut off by a fault of great throw, but they reappear again on the south side of the valley, forming a broad band extending eastwards from the northern slopes of Loi Ling, across the head of the Nám-pawng and Nám-hsawm valleys towards the Salween.

Loi Ling.

At its south-western end this band merges into the huge mass of Loi Ling, which rises abruptly, like an island set in the sea, to a height of some 6,000 feet above the undulating plateau surrounding it (Plate 1). Indeed, it seems not improbable that these ancient rocks did form islands or shoals in the midst of the Palæozoic ocean, for the rocks that were deposited upon them thin out in a remarkable manner as they approach the inliers; the lowest fossiliferous rocks forming a

very narrow ribbon separating the Plateau Limestones from the slaty series, or in many places not appearing at the surface at all, the limestones overlapping them and resting directly upon the slates and quartzites.

Hills east of Mong-Yai (Section III, Plate 24).

To the south-east of Loi Ling these rocks occupy an irregular area, the structure of which is by no means easy to unravel. In fact, the details, as shown on the map, must be considered as merely an approximation, more or less close, to the truth. The whole tract is a maze of hills densely covered with jungle, and the only means of arriving at any knowledge of the rocks is to make traverses as far as possible across the strike, and correlate the scattered observations thus made of outcrops, often at considerable distances apart, with each other. It is quite impossible to follow up the outcrop of any particular bed from one point to another, and as the paths almost invariably run directly across the ranges, it is seldom that they coincide in direction for more than a few yards at a time with the general strike of the rocks. It is therefore difficult to obtain any accurate conception of the general structure of this mass of hills, but briefly it may be described as that of a series of elongated domes, whose axes run more or less directly north and south. These have been broken up by a complicated set of great faults, whereby huge wedge-shaped masses of the overlying strata have been let down among the older rocks, some of the faults striking in a direction almost parallel to the axes of the domes, while others cut directly across them. The quartzites and slates occupy the core of the domes, and rise into lofty ridges and peaks, attaining altitudes of between 4,000 to 6,000 feet above the level of the sea.

Loi Pan—Loi Twang ranges.

Another detached area of these rocks is found to the south of the plateau, in the sub State of Möng Tung, forming a conspicuous mountain mass rising in Loi Pan to a height of 6,693 feet above sea level, and extending to the south into the Southern Shan States of Möng Küng and Kehsi Mansam, the three States meeting along the ridge of Loi Twang, 5,752 feet, at the southern end of the range. The northern portion of this range is composed of the ordinary slates and quartzites of the Chaung-Magyi series, rising abruptly from the surrounding limestone plateau, without any intervening fringe of the lower Palæozoic rocks. The prevailing strike of the rocks is from north-east to south-west, but it is, as

usual, by no means constant. About the latitude of Möng Tung village (**H** 4), the strike becomes transverse to the general direction of the range, and a change in the character of the rock sets in. The quartzites are replaced by grits and sandstones of quite unaltered appearance, on the bedded surfaces of which ripple marks are often visible, and the slates by unaltered yellow shales. But in spite of their unaltered appearance none of these rocks contain a trace of organic remains, and there seems to be no reason for ascribing to them a later age than that of the quartzites and slates. The alteration of the latter indeed seems to be merely a local characteristic, and to be due to the intrusion of large dykes of granite among the rocks at the northern end of the range.

Changes of strike.

The sandstones and shales form the whole of the lofty ridge of Loi Twang, and from a short distance to the south of Möng Tung are found to be striking in a north and south direction, parallel to that of the range. This abrupt change of strike is a feature not easily to be accounted for, but we have seen above that such changes of strike occur elsewhere among these old rocks, and they may be due to distinct and successive periods of earth movements. There is ample evidence that the pre-fossiliferous rocks were folded and dislocated, perhaps by forces acting from different directions at successive intervals of time, before the deposition of the overlying strata. The final thrust, which has affected all the rocks of earlier date than the Tertiary, seems to have come from the south-east or perhaps the east, since the direction of the folds and dislocations that have affected the Jurassic Namyau beds is usually from N.-N. E.to S.-S. W.

Age of the Chaung-Magyi series.

The absence of fossils in the Chaung-Magyi rocks makes any attempt to determine their geological age a matter of uncertainty, as is always the case where stratigraphical position and lithological resemblances are the only guides we can appeal to. As regards their position in the geological sequence we have the fact that these rocks had been deposited, consolidated, thrown into folds and dislocated, and finally subjected to denudation before the accumulation upon them of strata containing Ordovician fossils. No beds containing Cambrian fossils, which would bridge over the interval of time that must have elapsed between these events, have yet been found either in the Shan States or the neighbouring districts nearer than Yunnan; and it would therefore seem that,

taking the stratigraphical evidence alone into consideration, the Chaung-Magyi rocks should be considered as pre-Cambrian. So far, however, as the lithological evidence goes there is no reason why they should not be placed in the lowest division of the Cambrian system, for they show very slight traces of alteration, the so-called quartzites being often indistinguishing under the microscope from ordinary sandstones, while in only a few instances has a secondary growth of the quartz grains been detected. The drawn out patches of ferruginous matter referred to on page 48 as characteristic of the slates and probably representing granules of oxidised pyrites are practically the only signs of alteration that these beds show, and I would not have been surprised at any time to find traces of organisms in them. I have, however, searched carefully through many outcrops, especially of the black carbonaceous shale which occurs in places, without discovering any sign of a fossil.

No organic remains.

I have been much struck with the resemblance between these beds and those of the Shillong series in the Khasi Hills of Assam. Both series are made up of slaty shales and quartzites, and the soft, sandy character of the latter rocks in the Khasi Hills, especially in weathered outcrops, is identical with that of the Chaung-Magyi quartzites. The series resemble each other also in containing no trace whatever of interbedded limestones.

Comparison with Shillong series.

The Shillong quartzites and slates have been conjecturally correlated, both by Sir T. Holland[1] and Mr. Vredenburg,[2] with the Dharwar system of Southern India, but their similarity with the Chaung-Magyi rocks leads me to think that they are perhaps of not so great an antiquity. It seems to me much more probable that the crystalline limestones, with the associated pyroxene and scapolite gneisses and granulites of the Ruby Mines represent the Dharwar system in this area, and that, like the Dharwars of the Indian peninsula, they will be found to be folded in among the biotite gneisses along definite lines. If this is the case, the Chaung-Magyi rocks, the alteration of which is absolutely *nil* in comparison with that of the highly metamorphosed crystallines of the Ruby Mines area, must be much younger in age. They would correspond then

Correlation with Dharwars doubtful.

[1] Sketch of the Mineral Resources of India, p. 2.
[2] A Summary of the Geology of India, Calcutta, 1907, p. 16.

to some portion of the Purana group of Sir T. Holland,[1] including such series as the Bijawars and Cuddapahs of the Indian Peninsula.

Comparison with Hu-t'o system of China.

It seems possible that the Chaung-Magyi series of the Shan States may correspond with the Hu-t'o system (neo-Proterozoic) of Northern Shan-si in China,[2] though no limestones occur among them in our region. If this is the case, they should be regarded as pre-Cambrian, for in China they are succeeded by a series of strata, the Sinian system, in the lower part of which Cambrian fossils are found.[3] The fact that the Cambrian beds of China are related by their fauna to those of Spiti in the Central Himalaya and of the Salt Range in the Punjab[4] suggests that, although there does not seem to have been a direct communication between the two Provinces, they were deposited on either side of a great land area, and that in Cambrian times the Chinese sea did not extend so far to the south-west as the Shan States, submergence of the latter not taking place until Ordovician times. The nearest point in this direction at which fossiliferous Cambrian strata have been found is in southern Yunnan, where M. Lantenois [5] has described a series of finely laminated slaty shales, sandstones, and limestone bands in the valley of the Ta-Ho river, near I-liang Hsien (Y-Léang) to the east of Yunnan-Fu, containing *Olenellus* (*Mesonacis*) *Verneaui* Mansuy, *Lingulella* cf. *primæva* Hicks, *Obolella* sp., etc. The beds occupy an area of about 50 kilometres in length and 20 in breadth, and are overlaid by limestones of middle Devonian or of Carboniferous age. Strata corresponding in every respect with the Chaung-Magyi series were also found in Yunnan by Mr. Coggin Brown, and they probably correspond to the 'untersinische schichten', of Richthofen and Lorenz in Shan-tung.

The conditions that immediately preceded the deposition of the Ordovician strata in the Shan States appear to have been very similar

[1] Imperial Gazetteer of India, 1904, Vol. I, Chap. II, p. 9.

[2] Bailey Willis, Research in China; Carnegie Institution, Washington, (1907), Vol. I, Pt. I, p. 123.

[3] W. Dames in V. Richthofen's China, Vol. IV, pp. 1—33: E. Kayser, *Ibid*, pp. 34—36: C. D. Walcott, Cambrian Faunas of China, *Proc. U. S. Nat. Mus.*, Vol. XXIX, p. 1; Vol. XXX, p. 563: Bailey Willis, *Op. cit.*, Vol. I, Pt. 1, pp. 29, 34; Vol. II, p. 40: Th. Lorenz, Beiträge zur Geologie und Palæontologie von Ostasien; *Zeitschr. d Deutsch. Geol. Gesellesch.*, Bd. LVII, p. 441; Bd. LVIII, p. 81.

[4] F. R. Cowper Reed, Cambrian Fauna of Spiti; *Pal. Ind.*, Ser. XV, Vol. VII, Mem. No. 1, p. 69: Pre-Carboniferous Life-Provinces; *Records, Geol. Surv. Ind.*, Vol. XL, Pt. 1, p. 10. K. Redlich, Cambrian Fauna of the Eastern Salt Range; *Pal. Ind.*, New Ser., Vol. I, Mem, No. 1, p. 12.

[5] Mission Géologique et Minière du Yunnan Méridionale; *Annales des Mines*, Ser.10, Vol. XI, p. 308, *seq.*

to those obtaining in China at the beginning of the Sinian period, as conjectured by Bailey Willis[1] (*see below*, p. 349).

Bawdwin Volcanic Stage.

Lithological characters and distribution.

At certain localities along the boundary between the rocks just described and the overlying fossiliferous Palæozoic formations a series of beds is exposed which are undoubtedly of volcanic origin. These consist mainly of tuff or ash beds, but among them layers of true rhyolites are interstratified, the remains of ancient lava flows. The most important development of these beds that has yet been met with occurs at Bawdwin, or Bawdwingyi (*Burm.* 'The great Silver mine'), the northern part of the Tawng-Peng sub-State, a few miles to the west of the Nám-Tu, beyond the northern limits of the map. This place is well known as the site, for many hundreds of years, of extensive mining operations on the part of the Chinese, who extracted very large quantities of silver-bearing lead ores from the rocks, and who have left abundant traces of their activity in the enormous heaps of lead slag, now being exploited by a smelting company, covering the hill slopes surrounding the mines, and in the numerous adits and galleries with which the hills are honeycombed. An account of the geology and mineralogy of these mines will be found in the *Records* of the Geological Survey of India, Vol. XXXVII, Pt. 3, the result of observations made by Mr. J. Coggin Brown and myself during a visit to the mines in February 1907. At the time of our visit the Company had not yet begun operations, beyond prospecting the slag heaps, and the place was in much the same state as when the Chinese deserted it, owing, it is supposed, to political troubles and the incursions of the Kachins, over 50 years ago. For the present it is sufficient to say that the ores occur among the tuffs and rhyolites of the volcanic series, and that the mineralisation of the rocks is due to the presence of a great dislocation or overthrust, in the neighbourhood of which they are intensely crushed and shattered.

Bawdwin silver mines.

Overthrust fault.

This dislocation is one of the most striking features of the structure of the rocks in this part of the Shan Hills, and it has been traced for many

[1] *Op. cit.*, Vol. II, p. 32.

miles to the south of Bawdwin, running parallel to the Nám-Tu. It will be dealt with more fully later on, in connection with the description of the lower Palæozoic rocks (*see* p. 136). At Bawdwin it runs almost due north and south, and its effects are abundantly noticeable in the twisted and shattered condition of the strata in its vicinity. Unfortunately the country round Bawdwin has not yet been topographically surveyed on a sufficiently large scale to enable the relations of these rocks to the strata under and overlying them to be clearly made out, and it is as yet uncertain whether they should be classed with the Chaung-Magyi series, or with the lowest group of fossiliferous rocks.

Extension to south and south-east.

To the south of Bawdwin these volcanic beds are almost everywhere overlapped by Silurian sandstones, and only appear at one or two places; at Longtawktao (F 1); further to the south at Kunhawt (E 1), where there is a small exposure of sphærulitic rhyolite, and between the latter place and Hunang (E 2). In the ranges east of the plateau they are found along the crest of the Loi-len range east of Lashio; among the hills between Möng-Yai and the valley of the Nám-Há; and on the west side of Loi Twang. Where present, they invariably occur between the Chaung-Magyi rocks and the lowest member of the fossiliferous series, but they do not form a continuous band, and had evidently either been subjected to aerial denudation before the deposition of the latter, or are overlapped by higher beds.

Petrographical characters.

The Bawdwin rhyolites exhibit the usual phenomena observed in acid glassy lavas, such as flow, sphærulitic and perlitic structures, corrosion of the quartz phenocrysts, and the like (Plate 6, fig. 1). The groundmass is always cryptocrystalline having probably undergone a certain amount of devitrification, and sometimes exhibits the peculiar breaking up into irregular areas, alternately light and dark under crossed nicols, known as a "quartz mosaic."

This structure is exactly the same as that which occurs in some of the Malani rhyolites of Western Rajputana of pre-Vindhyan age; and in the rocks from both localities, wherever this structure occurs, the quartz phenocrysts are surrounded by a "court" or closed area (Plate 6, fig. 2), the quartz of which is in optical continuity

[1] T. D. LaTouche, Geology of Western Rajputana: *Memoirs, Geol. Surv. Ind.*, Vol. XXXV, Pt. I, p. 83.

with that of the phenocryst, and extinguishes simultaneously with it under crossed nicols.[1] On the other hand, precisely the same structure has been shown by Dr. Fermor[1] to occur in the rhyolites of Pavagad Hill, in the Panch Mahals district, Bombay Presidency, which are interbedded with Deccan Traps, and are therefore of Cretaceous age. The presence of this structure cannot therefore be taken as evidence of similarity in age between the Bawdwin and Malani rhyolites; but in other respects, such as the preponderance of quartz phenocrysts over those of felspar, the absence of plagioclase felspar and of augite, they both resemble each other, and differ from the lavas of Pavagad Hill, as described by Dr. Fermor.

There can be no doubt that the Bawdwin rhyolites are older than Ordovician, and they must therefore belong to a period not very far removed from that of the outpouring of the Malani lavas.

The felspars of the Bawdwin rhyolites are usually quite decomposed, both in the phenocrysts and in the groundmass, and are represented by a fibrous, felted mass of (?) sericite, which also fills cracks in the groundmass. Where the felspar is not decomposed it is invariably orthoclase; sometimes the outlines of the crystals are still preserved, and in some cases traces of simple twinning are still visible. Iron ores, exhibiting the white mesh-work characteristic of leucoxene, are usually present, but I have found no trace of any of the ferromagnesian minerals, or of mica.

Mineralisation.

Mr. Coggin Brown has shown that the mineralisation of the rock consists in the metasomatic replacement of the felspar, both of that in the groundmass and the phenocrysts, by galena and other sulphides. In the final stages of the process the quartz grains were also attacked, and "specimens can be found showing only a very small proportion of the original minerals replaced by sulphides, through others composed of sulphide ores and a large amount of quartz, and finally those which consist almost entirely of sulphides, with very little quartz."[2]

Structures in rhyolite.

At Bawdwin itself sphærulitic lavas have not been met with, but in some specimens perlitic cracks are seen traversing the quartz phenocrysts and occasionally extending beyond their borders into the groundmass. Sphærulites occur, however, at some other localities, at Kunhawt,

[1] On the Lavas of Pavagad Hill; *Records, Geol. Surv. Ind.*, Vol. XXXIV, Pt. 3, pp. 154, 160.

[2] The Silver-lead mines of Bawdwin; *Ibid*, Vol. XXXVII, p. 251.

for instance, and in the exposure at Wantawng (**G** 5) on the west side of the Loi Twang range (Reg. Nos. 17/796, 19/966).[1] A lava with large sphærulites is also found on the pass between Nawa (**I** 3) and Möng Yai, the capital of South Hsenwi, in the ranges south of Loi Ling (Reg. No. 20/957).

Tuffs.

The tuffs form by far the greater part of the bulk of these deposits, the flows of rhyolite being quite subordinate. They resemble the latter in composition, and consist of fragments of quartz and felspar imbedded in a fine-grained matrix of volcanic dust. It is interesting to find that occasionally a fragment of rhyolite occurs in the matrix, showing the mosaic structure of the groundmass referred to above. This observation seems to prove that this structure must have been developed in the lavas at the time of their consolidation, as I have already contended in my account of the Malani rhyolites (*Loc. cit.*, pp. 84, 89), and is not due to devitrification of the groundmass at a later period. In this contention I am supported by Dr. Fermor, who came to the same general conclusion from his study of the lavas of Pavagad Hill (*Op. cit.*, p. 163), though he is inclined to think, arguing from the case of a granite from Singbhum, in which a similar mosaic occurs, that the development of the structure was not absolutely contemporaneous with the primary solidification of the rock, but took place immediately afterwards, while the mass was still hot, and is to that extent of a secondary nature.

The felspar of the tuffs is generally in as decomposed a condition as that of the lavas, and is replaced in the same way by sulphide ores in the neighbourhood of the great Bawdwin overthrust.

Period of volcanic activity.

It seems to be a reasonable hypothesis that the Chaung-Magyi series and the older crystalline rocks formed in early Palæozoic times a land surface, perhaps with a cluster of detached islands or shoals to the south-east of the main area, the shores of which were washed by the seas in which the succeeding fossiliferous strata were deposited. These older rocks had been folded, upheaved, and greatly denuded before this deposition occurred, and it seems not unlikely that, at some time during this period of disturbance, volcanic forces became active, and, if so, that the most probable places in which the outbreaks would occur would be situated along the shores of this

[1] These numbers refer to the register of rock specimens in the Geological Survey Museum.

ancient land. Under such circumstances it would be quite natural that the volcanic deposits would be partly removed by denudation, either marine or sub-aerial, and partly overlapped and concealed by the succeeding strata, so soon as the conditions became favourable for the deposition of the latter. It may be conjectured, therefore, that the volcanic rocks belong neither to the period of deposition of the Chaung-Magyi series nor to that of the succeeding formations, but occupy an intermediate position. As they participated in the disturbances that affected the Chaung-Magyi series, and are not fossiliferous, but formed a portion of the rocky floor on which the succeeding formations, the age of which can be determined by fossils, were laid down, I prefer to classify them for the present with the older rocks.

Intrusive Rocks.

Intrusive granite.

Among the Chaung-Magyi rocks great intrusions of granite are found in some places, especially in the main area in Tawng Peng, which may perhaps belong to the same period as that in which the ejection of the rhyolites took place. These rocks are especially conspicuous in the neighbourhood of Nám Hsan (**E** 1), the capital of the Tawng Peng State, which is built upon them near their eastern edge, and where they occupy a large area, extending for several miles to the south, west, and north. Large dykes of granite also proceed from this granitic expanse towards the north-east, to within a few miles of the rhyolitic area of Bawdwin. Intrusions of granite also occur among the Chaung-Magyi rocks on the north side of Loi Pan, in Möng Tung State, and along the southern slopes of Loi Ling in South Hsenwi.

Petrographical characters.

The rock is an ordinary granite, consisting of quartz, orthoclase, felspar, sometimes microcline, and biotite, and it usually bears evidence of intense curshing. The felspar in a mass of granite, capping a hill at Loihkam (**D** 1), 21 miles west from Nám Hsan, consists almost entirely of microcline. It differs from the granite of the Ruby Mines district, described above, in containing no tourmaline.

Intrusions of basic rocks.

It is somewhat remarkable that instances of the intrusion of basic rocks are exceedingly rare in that part of the Shan States described in the present Memoir. Throughout the whole of the periods

represented by the fossiliferous Palæozoic and Mesozoic strata volcanic activity of every kind seems to have been in abeyance, and it is not until we reach quite late Tertiary times that we find evidences of such forces being still in existence beneath the surface. Such basic intrusions as do occur are confined to the oldest rocks, and are of rare occurrence in them. One small dyke was met with among the mica schists to the south of the Ruby Mines, between the villages of Hpalam (**C** 1) and Nalaw, 13 miles east-south-east of Mogôk. This rock (Reg. No. 15/966) is a dark greenish diorite with a specific gravity of 2·873, consisting of plagioclase felspar (labradorite), and pale green hornblende. The latter forms a minutely crystalline cataclastic groundmass ophitically surrounding the felspar (Plate 7, fig. 1). The only accessory minerals are scattered granules of iron ore, the surface of which shows by reflected light the white meshwork characteristic of leucoxene, and a few very minute needles of apatite. The whole rock is remarkably fresh looking, and the hornblende may be of secondary origin, in which case it should be styled an epidiorite. The rock differs entirely from the Tertiary dykes of Burma in containing no olivine, and I am not aware of any other locality in which a similar rock occurs in this region.

Diorite near Hpalam.

The only other locality in which basic dykes, older than the Tertiary period, have been found is in the neighbourhood of Nám Hsan, near the eastern edge of the granite area, into which they have been intruded. This rock (Reg. Nos. 17/792, 20/559) is quite different from that described above. It is a coarse-grained, dense, black, holocrystalline rock with a specific gravity of from 3·012 to 3·04. The constituents are—olivine in large granules with a peculiar violet-brown tinge; plagioclase felspar, either a basic variety of andesine, or labradorite; and colourless augite, the latter ophitically surrounding the olivine and felspar. The rock is interesting on account of its resemblance in some respects to the olivine norite from a dyke in South Rewa collected by Mr. Datta and described by Sir T. Holland in the *Records, Geol. Survey of India* (Vol. XXX, Pt. I, p. 20), although the Nám Hsan rock does not contain enstatite, and cannot therefore be called a norite. The resemblance lies in the similarity in the colour of the olivine phenocrysts, which is perhaps due to the presence of manganese, and in the development of a narrow "reaction rim" surrounding the olivine crystals, wherever they are in contact with

Olivine-gabbro.

the felspars (Plate 8, figs. 1, 2). This rim consists, as in the S. Rewa rock, of two zones, the inner very narrow, composed of a colourless minutely granular mineral, while the outer zone, which is often much broader, consists of a finely fibrous, also colourless mineral, which may be either actinolite or tremolite. In the S. Rewa rock the inner zone was considered by Sir T. Holland to be enstatite, on account of its optical continuity with the adjoining crystals of that mineral, but the Nám Hsan rock does not contain any enstatite, and it cannot therefore be determined to what species the mineral of the inner zone must be referred. The "reaction rim" is entirely absent where the olivine comes into contact with the augite, but it sometimes expands into the interstices between the other constituents of the rock. A little mica is sometimes included in it. The peculiar colour of the olivine, which is perhaps more pronounced in the Nám Hsan rock than in that from S. Rewa, is seen, under a high power, to be due to inclusions of dusty matter, some of which may be manganese, for Dr. Fermor informs me that a trace of this mineral occurs in the Nám Hsan rock, and the analysis given on p. 20 of Sir T. Holland's paper shows that it occurs in his specimen also.

The felspar is a variety giving a fairly high angle of extinction, either a basic andesine or labradorite. It possesses a light reddish brown colour, due to the presence of minute inclusions. This character is exactly similar to that noted by Sir T. Holland in the felspars of some of the other rocks described in the same paper, notably in the olivine norites from Singapuram, Salem district (Reg. No. 9/398, p. 24), and Vitlapuram, South Arcot (Reg. No. 9/811, p. 25); but whereas in the two latter rocks the colour is more pronounced in the centre of the crystals, fading away towards their edges, in the Nám Hsan rock it is concentrated along the edges of the crystals. The peculiar colour of the olivine is more pronounced in these rocks from Salem and South Arcot than in that from S. Rewa. One important point of difference between the Nám Hsan rock and those from S. India may be noted, namely, that in the former the felspar has crystallised before the augite, which surrounds it ophitically, whereas in the latter the felspar has been the last mineral to consolidate. Magnetite in fairly large quantities, and a little biotite, are the only accessory minerals that I have been able to detect in the Nám Hsan rock.

Age of the dykes.

The South Indian dykes are intrusive in rocks belonging to the Dharwar series, and are probably contemporaneous with the trap flows in the Cuddapah series of that area (Holland, *Op. cit.*, pp. 36, 37). Those of Nám Hsan must belong to a somewhat later period, for they are intrusive in the granite, which is itself intrusive in the rocks of the Chaung-Magyi series, and I have already given reasons for supposing that this series is of later age than the Dharwars. The Nám Hsan rock is quite different from the Tertiary olivine basalts of Loi Han Hun, described by me in the *Records, Geol. Survey of India,* Vol. XXXVI, Pt. 1, p. 42, and referred to below (p. 314).

From a sketch by the author.

FIG. 3. The Chaung-Magyi at Gwegyaung. Hpataunggyi in the distance.

CHAPTER VI.

ORDOVICIAN SYSTEM.

Nomenclature.

In studying the geology of an area that has not been previously surveyed it is convenient, and in most cases absolutely necessary, to give local names to the formations met with; and the names that naturally occur to the surveyor are those of villages, hills, rivers, etc., in the vicinity of which he first meets with that particular formation. Moreover, if two observers are working in the same region, and are, as so often happens in this country, unable to communicate with each other, different names are apt to be given to the same formation, especially when the character of the country is such that it is difficult to correlate one set of observations with another by mere description of the rocks which each individual has met with. It is for this reason that so many discrepancies will be found in the accounts of the geology of the Shan States originally published in the General Report of the Geological Survey of India for 1899-1900 by Mr. Middlemiss, Mr. Datta, and myself. Indeed, so widely did the interpretation that each of us put upon the observations we had made differ from each other, that it was thought advisable at the time to publish each description separately, leaving it to future investigation to reconcile the points of difference. The names given by Dr. Noetling also, during his rapid traverse of the same ground in 1890, do not correspond with ours. For instance, his 'Pyintha limestones,' of lower Silurian age, were found to include beds belonging to both the Ordovician and Silurian systems, and were subdivided by me into the Zebingyi beds (upper Silurian), Nyaungbaw and Naungkangyi beds (Ordovician). Also his 'Mandalay limestones,' which he placed beneath the Pyintha limestone, have since been found to include strata of Devonian age.

Correlation with European systems.

As the survey of such a country proceeds, however, some of the names at first given to the formations are found to be inconvenient, or not sufficiently comprehensive; others are rejected, as the identity of the strata becomes apparent, to which at first separate names had been given in different localities; while, as the collections of fossils expand, and the genera and species to which they belong are determined, it becomes possible to correlate the forma-

tions more or less closely with those in far distant regions, in which the geological nomenclature is already established. Thus it is possible in the Shan States to give the well-known European designations to those larger groups of strata which we call systems: and it would be mere affectation to call these groups by local names, where there is such a close agreement in the whole assemblage of fossils as we find in the present case. For although there may be truth in the contention that this very agreement in specific characters is evidence that the beds in which the fossils occur cannot be strictly contemporaneous, when we are dealing with localities at great distances apart (since it presupposes a migration of forms, which must have occupied a certain amount of time, from one area to another), yet such an objection cannot apply to the general contemporaneity of a whole system. If, moreover, as seems to be generally admitted, the present zonal distribution of climate on the earth's surface was not established till late in the world's history, the objections to the contemporaneous existence of identical forms of life in areas widely differing in latitude lose much of their force.

Names of sub-divisions.

In the following descriptions of the fossiliferous rocks of the Shan States, therefore, I propose to use the well-known names already in use as applied to the systems; but the case is different as regards the sub-divisions of which those systems are composed. Until the geology of Western China, especially of Yunnan, and of Central Asia is better known, it is not possible to trace these minor divisions beyond the confines of the Shan States, and as some of them appear to be as closely connected by their fossil contents with strata already described in North America as with those of northern Europe, very much remains to be done before we can determine which system of classification is to be adopted. Moreover, as our future surveys will probably take the Shan States as a centre, it is convenient to employ a local standard of position to which to refer. It is only when the formations have been linked up with those beyond the barrier of unexplored or little-known territory that it will be possible to adopt a more widely accepted nomenclature.

Discrepancy between Burmese and Himalayan geology.

The name 'Ordovician,' as that of a separate system, has not until now been employed by Indian geologists, and the reasons for its use here perhaps require some explanation My object in doing so is to emphasise at the outset the great want of accordance

that has been found to exist between the geology of eastern Upper Burma and that of India proper. This discrepancy was at once noticed by Dr. Noetling,[1] and further discoveries have shown that it is much wider than even he supposed. He says :—

"The presence of such a characteristic form as an *Echinosphærites* even permits the identification of the exact horizon of the red limestone (*i.e.*, the Pyintha limestone). It is an equivalent of the *Echinosphærites* limestone of the Baltic provinces. It not only contains the same fossils but also strongly resembles the latter lithologically. How can we account for such a strange phenomenon as this ? We find here a fauna under 22° northern latitude which is precisely the same as that found in the Baltic provinces (59° to 66° N. Lat.), whilst the Silurian fauna of the Himalayas approaches much closer to the Silurians of Central Europe. The fauna of the lower Silurians of the Himalayas is as different from that of the Shan hills as is the Silurian fauna of Bohemia from that of England. It must therefore be assumed that a branch of the Arctic province of the ocean by which the lower Silurian beds were deposited, reached at least to 22° N. Lat., of the Indo-Chinese peninsula ; it is even likely that it extended still further to the south, as the limestone beds of the Shan hills are again met with in Tenasserim."

Occurrence of Cystideans.

It is a curious point that the fossil on which these remarks were based, described by Dr. Noetling in the paper quoted above as a gigantic species of *Echinosphærites*, and named *E. Kingi*, has turned out, on further examination, not to belong to that genus at all but to be a *Camarocrinus* allied to the Bohemian genus *Lobolithus*, occurring in the lower Helderberg beds of America. Subsequent investigation has shown, however, that the beds beneath the red limestone, in which this fossil was found, are characterised by the presence throughout of well preserved specimens and enormous numbers of detached plates of true cystideans, all of which, "with the exception of *Aristocystis*, are especially characteristic of the lower Ordovician beds of Northern Europe and particularly of the Russian Baltic Provinces."[2] Thus Dr. Noetling's observation, though depending on imperfect knowledge, has been justified by the results of further research.

List of formations.

The formations comprising the Ordovician system in the Shan States have received the following names, in descending order :—

(Nyaungbaw Limestone.)
Hwe Mawng Purple Shales.

[1] Field Notes from the Shan Hills ; *Records, Geol. Surv. Ind.*, Vol. XXIII, Pt. 2, p. 79 : also Ann. Report for 1890, *Ibid*, Vol. XXIV, Pt. 1, p. 12.

[2] F. R. Cowper Reed, Lower Palæozoic Fossils of the N. Shan States ; *Pal. Ind.*, *New Ser.*, Vol. II, Mem. No. 3, p. 85.

Upper Naungkangyi Stage.
Lower Naungkangyi Stage.
(Ngwetaung Sandstones.)

As will be explained below in dealing with each formation, this sequence is not universally present, the members of it enclosed in brackets being extremely local in occurrence, while there is a very close connection between the upper Naungkangyi beds and the purple shales of Hwe Mawng. In fact it is only for convenience of description, since they occur in widely separated areas, and it is not yet certain how far they are mutually equivalent, that different names are now given to them.

Ngwetaung Sandstones.

Lithological characters and distribution.

These beds consist of coarse to fine-grained brown sandstones usually with a somewhat calcareous matrix and sometimes enclosing thin lenticular bands of limestone, forming the crest and western slopes of the high range of hills culminating in the peak of Ngwetaung (3,403 ft. **B** 5), which rises boldly from the foot-hills due east of Mandalay, and is distinctly visible from that place. These sandstones, so far as has been ascertained, contain no characteristic fossils, the only remains found in them being scattered fragments of crinoid stems, and a few very ill-preserved specimens of a small *Orthis* (*O. testudinaria* Dalman). They are separated off from the more fossiliferous beds overlying them because they seem to be of extremely local development, and because none of the characteristic fossils of the higher beds, with the exception of the doubtful *Orthis* mentioned above, have been found in them. To the west they are cut off by a fault, the rocks forming the western side of the longitudinal valley separating Ngwetaung from the foot-hills being Devonian limestones. They may perhaps appear a little further east, on the eastern side of the Kyet-maôk valley above Taunggaung, being brought up by a parallel fault, but no fossils were found in them here, and it was found impossible, owing to the want of clear sections, to separate them distinctly from the underlying Chaung-Magyi rocks. They have not been found in any other locality at the base of the fossiliferous series, though they may perhaps be represented on the southern slopes of the Loi-len range to the east of Lashio, where

Fossils.

one or two specimens of *O. testudinaria* were picked up near the crest.

Lower Naungkangyi Stage.

Nomenclature.

The name Naungkangyi was given to these rocks from a village lying two and a half miles to the north of Maymyo, because the first remains of true Cystidean plates were found in 1899, at the point where the path leading to this village crosses the low hills north of the railway station. The actual beds in which these fossils were discovered have since been found to belong to the upper part of a great series which has a wide distribution in the Shan States, from which large collections of fossils have been made and submitted for description to Mr. F. R. Cowper Reed. The collections were sent to him in 1903, before the stratigraphical details of the series had been worked out, and for this reason the whole of the fossils were described as coming from the Naungkangyi beds; and the results of his investigations having already been published in the Palæontologia Indica (*New Series*, Vol. II, Memoir No. 3), I consider it advisable to retain the name for the whole group of strata from which the fossils were collected, though further investigation has shown that Mr. Reed was perfectly correct in saying that undoubtedly more than one stage was represented among them. Even now further research will almost certainly show that the dual division which I have made is incomplete, and the present classification must be understood as a rough approximation to the truth only.

Lithological characters.

The lower beds of this formation consist of yellow or buff-coloured sandy marls, with strong lenticular bands of coarsely crystalline limestone, all containing fossils. It is probable that the marly beds were originally calcareous, though they may now contain no trace of lime, and that their present condition is the result of the leaching out of the calcareous matter by weathering, for they are sometimes found to pass into solid limestone when excavated to a sufficient depth. Near Taungkyun (**B** 5), for instance, a village on the eastern side of Ngwetaung, where *Orthis* (*Dalmanella*) *elegantula* Dalman is exceedingly common, it occurs in what appears to be a fine grained pinkish-brown sandstone, but on digging into

the rock this is found to be a mere veneer, though often of considerable thickness, containing no trace of calcareous matter, on a hard dense blue limestone, in which no fossils can be detected, though it is quite certain that the outer sandy coating is a direct result of the weathering of the limestones.

List of fossils.

The fossils occurring in the lower portion of the Naungkangyi group of strata are the following. The names of new species are printed in heavier type:—

Cystidea :—

Aristocystis **dagon** Bather
Heliocrinus **fiscella** Bather
,, **rugatus** Bather
,, **qualus** Bather
,, sp.
Echinoencrinus aff. *Senckenbergi* E. V. Meyer
Cheirocrinus sp.
Caryocrinus **turbo** Bather
,, **avellana** Bather
,, **aurora** Bather
,, sp.
Protocrinus **sparsiporus** Bather

Bryozoa :—

Escharopora sp.
Rhinidictya cf. *plumula* Salter
,, sp.
Phylloporina **orientalis** Reed
Diplotrypa **sedavensis** Reed
,, sp.
Fistulipora sp.

Brachiopoda :—

Schizotreta cf. *elliptica* Kutorga
Rafinesquina imbrex Pander
,, **subdeltoidea** Reed
Leptæna (?) **ledetensis** Reed
Plectambonitesquinquecostata McCoy
,, *sericea* Sowerby
Chonetes (?) **thebavensis** Reed

Orthis calligramma Dalman
,, (*Dalmanella*) *testudinaria* Dalman
,, (,,) *elegantula* Dalman
,, (,, ?) **chaungzonensis** Reed
,, (*Dinorthis*) *flabellulum* Sowerby
,, **irravadica** Reed
,, **subcrateroides** Reed
Clitambonites cf. *pyron* Eichwald
,, cf. *squamata* Pahlen
Porambonites intercedens Pander

Arthropoda :—

Calymene **birmanica** Reed

Incertæ sedis :—

Cyclocrinus cf. *Spasski* Eichwald

Difficulty of correlating separate outcrops.

The great variation in the lithological character of the rocks at the different localities from which the fossils have been collected, and the fact that in many cases, particular forms have only been found in one locality, renders it extremely difficult to trace any connection between the occurrences at one place or another. Thus at Sedaw (Loc. 88, **B** 5), where all the Cystideans described by Dr. Bather were obtained, the fossils are found weathering out as hard limestone nodules from a thick band of papery shales, which have been met with nowhere else; but where the railway crosses the strike of these beds, above the fourth Reversing station at the head of the sharp ascent from Sedaw to the Zebingyi plateau the only rocks seen are hard thin-bedded grey and reddish limestones, in which only the faintest traces of fossils have been detected. Nothing like the papery shales in the ravine below is to be seen either to the north or south of the Sedaw valley. It will be necessary therefore to describe each outcrop, where collections of fossils have been made, separately, and only to attempt to correlate them with each other when such a course seems to be justified by a similarity in the fauna.

Fossils, Sedaw.

The beds at Sedaw in which the Cystideans mentioned above occur may be reached by taking a path which leads up the left bank of the Sedaw river from

the station to the back of the hill up which the zig-zags of the railway are carried. This hill is composed of Devonian limestones, which are separated from the Ordovician rocks by a fault running north and south along the bed of the ravine at the back of the hill, and crossing the railway just below the third Reversing station, where the crushed and slickensided aspect of the soft Ordovician limestones and shales is very conspicuous. The fossils are found scattered over the slopes on the eastern side of the ravine, and are sometimes found embedded in the shales. They comprise :—*Aristocystis dagon*, *Heliocrinus fiscella*, *H. rugatus*, *H. qualus*, *Caryocrinus turbo*, *C. avellana*, *C. aurora*, and *Protocrinus sparsiporus*, all new species determined by Dr. Bather; *Diplotrypa sedavensis* Reed; *D.* sp.; *Fistulipora* sp. *Schizotreta* cf. *elliptica* Kutorga; *Rafinesquina imbrex* Pander; *Clitambonites* cf. *pyron* Eichwald; and *Porambonites intercedens* Pander.

Cystideans.

Of these fossils *Aristocystis* is the only genus that has not been found elsewhere than in Bohemia. According to Dr. Bather[1] it has not yet been recorded from America, or from the Ordovician of either England or the Baltic Provinces. Only one species is recognised by Dr. Jaekel as belonging to the genus, namely, *A. bohemicus*, Barrande, and the Burmese species seems to be sufficiently distinct from this to warrant a specific name, though Dr. Bather calls attention to certain points of similarity.

Heliocrinus ranges from the base of the Llandeilo to upper Caradoc beds, and is of wide distribution in northern Europe. Of the new species described by Dr. Bather *H. fiscella* approaches most nearly to *H. balticus* Eichwald and *H. aranea* Schlotheim. *H. rugatus* resembles in its ornamentation *H. Helmhackeri* Barr. and *H. Rouvillei* v. Kœnen, but has a less projecting mouth and anus. *H. qualus* approaches in shape nearest to *H. confortatus* Barr. and in ornamentation to *H. granatum* Wahlenb. *Caryocrinus* is mainly confined to beds of Niagaran (Wenlock) age in the United States, but two species have been recorded from Scandinavia in strata of upper Ordovician age. The only other representative of the family hitherto recorded from Asia is *Hemicosmites*? *Loczyi* Jaekel,[2] from some marly crinoid limestones interstratified with yellow and varie-

[1] *Palæontologia Indica, New Series*, Vol. II, Mem. No. 3, p. 13, Pt. I, figs. 1-5.
[2] O. Jaekel, Stammesgeschichte der Pelmatozoen; I. Thecoidea und Cystoidea (Berlin, 1899), p. 315.

gated shales near Pu-pjao in south-western Yunnan, which resemble very closely, judging from Prof. v. Loczy's description, the Naungkangyi beds of the Shan States.[1]

Dr. Bather remarks, with reference to the new species of this genus described by him, that they all present certain primitive characters reminiscent of the Ordovician *Hemicosmites*, and that they differ in many respects from any known species of *Caryocrinus*. From which it would seem that the genus appeared in Burma before its occurrence in America. *Protocrinus* is known only from the lower and middle Ordovician of the Baltic Provinces and the upper Ordovician (Étage **D** 4) of Bohemia. The new species approaches *P. fragum* Eichw. but differs in important respects from all known species of the genus.

Bryozoa.

The bryozoan *Diplotrypa*, two species of which occur at Sedaw, is by far the most common fossil at that locality. It may be picked up in large numbers on the slopes of the ravine, and is often found *in situ*, weathering out like a small nodule from the shales. The genus, Mr. Cowper Reed says, is typically Ordovician, of wide distribution in northern Europe, and the sub-genus *Mesotrypa*, to which he refers the Sedaw species, comes from the Trenton shales (middle Ordovician) of America. The new species *D.* (*Mesotrypa*) *sedavensis*, described by him, bears a considerable resemblance to *M. Whiteavesi* Nich., from the Trenton limestone, and *M. regularis* Foord. The other, unnamed, species from this locality may be only a variety or stage in the growth of *M. sedavensis*, but it differs in the more discoidal, less elevated shape of the zoarium, in the rather larger relative size of the zoœcia, and the less numerous mesopores.

Fistulipora is a genus ranging from Devonian to Permian, and Mr. Cowper Reed remarks that it is unexpected to find a member of it so low down in the stratigraphical series, but that a species had been recorded from the Galena limestone (middle Ordovician) of Manitoba. The absence of a lunarium renders it possible that this form should be placed in the genus *Cyclotrypa* Ulrich.

[1] Reise des Grafen Bela Szechenyi in Ostasien ; Vol. I, p. 767, Vol. III, p. 21. My colleague Mr. Coggin Brown tells me that he passed through Pu-pjao on his way to Tali-fu in 1907, and that he is convinced that the shales in question belong to the Naungkangyi series. He was then much pressed for time and could find no fossils ; but he has since made a rich collection from these beds, which is now being worked out (*see* p. 117).

Brachiopoda.

Passing now to the brachiopoda, *Schizotreta* occurs typically in the Ordovician of Russia, and the species occurring at Sedaw is comparable with *S. elliptica* Kutorga, the type of the genus. *Rafinesquina* has a wide distribution in northern Europe and America, and the Sedaw form, *R. imbrex*, is a typical species of the lower Ordovician in both regions. It is also very widely distributed in the Naungkangyi beds of the Shan States, occurring both in the lower and upper portion of the series, and at most of the localities from which fossils have been collected. *Clitambonites* (*Orthisina*) *pyron*, to which Mr. Cowper Reed compares the specimen of this genus found at Sedaw, occurs in the Echinosphærite limestone (lower Llandeilo) of Russia. *Porambonites* ranges from Ordovician to lower Devonian, but it is most fully represented in the lower Ordovician of Russia and Scandinavia. *P. intercedens* Pander is the type of the genus.

Thickness not determinable.

It is impossible to give any exact estimate of the thickness of these strata exposed at Sedaw, and indeed it may be stated once for all that this is true for the whole area under description. In very few outcrops is the junction of any individual bed with those either over or underlying it visible, and in no single instance that I am aware of is the base and summit of a bed to be seen in one and the same section. No measurements of the thicknesses of strata can therefore be given, as they would only be misleading, and indeed the thickness of even the larger groups varies so greatly from one locality to another that measurements made at any one spot would only have a strictly local value.

East of Ngwetaung ridge.

The peculiar beds exposed at Sedaw are, as I have already mentioned, not found either to the north or south of that place. To the north the beds immediately overlying the sandstones of Ngwetaung along the eastern side of the ridge, were found to contain, in a soft yellow marl, fragments of cystideans, namely *Cheirocrinus* sp., a genus that has a very wide distribution both horizontally and vertically, ranging from the Baltic Provinces to Bohemia and North America, and through the whole Ordovician period; and a species of *Caryocrinus*. Specimens of these are very numerous in an outcrop in the bed of a stream at the foot of the ridge on the path from Taungkyun to Sibaing (Loc. 86, **B** 5). Thick bands of limestone

Interstratified limestone.

are interstratified with these beds in the neighbourhood, and extend along the base of the ridge to the north and south, but they have not yielded any recognisable fossils. Traces of argentiferous galena have been found near Taunggaung in the northern extension of these limestones, and a small shaft had been sunk at the spot, but it does not appear to have reached any considerable depth, and was probably put down by Chinese prospectors.

Reputed silver-lead mine.

The limestones and marls extend eastwards from the base of the Ngwetaung ridge for several miles to Sakangyi, but the whole of the ground hereabouts is so covered with jungle that exposures are rare, and of very small extent. A short distance south of Taungkyun (Loc. 87, **B** 5) some pinkish brown sandstones occur, crowded with specimens of *Orthis* (*Dalmanella*) *elegantula* Dalman, a well-known fossil of Caradoc age; the peculiar weathering of the rock in which these fossils occur has already been referred to (p. 67).

Fossils, Taungkyun.

Along the eastern side of the valley of the Kyetmaôk stream above Taunggaung the limestones can be traced, forming a line of conspicuous cliffs, and overlying the Chaung-Magyi rocks which are brought up by a fault running from north to south along the floor of the valley. The limestones disappear on the high ridge overlooking Aunglôk, (**B** 4), between that place and Memauk, being probably overlapped by beds of Silurian age, but they appear again along the lower slopes of the lofty scarp forming the western edge of the plateau, east of the Chaung-Magyi or Nám Pek river. Fossils were collected from some sandy beds weathered out from them between 600 and 1,300 feet above the valley, on the path leading up the scarp from Kyaukmo to Kyaukgyi, including *Rafinesquina*, *Orthis elegantula*, and Cystidean plates (Loc. 80, **B** 3). Kyaukmo is the site of a magnificent waterfall, which descends the whole height of the scarp here, about 2,000 feet above the valley, and is clearly visible from the Irrawaddy in clear weather (Fig. 4, p. 124). Its position is shown on the geological map attached to Dr. Oldham's account of the geology of the country north of Mandalay, published as an appendix to Yule's narrative of the Mission to the Court of Ava in 1855 (p. 350). Beyond this the limestones have been traced to the north as far as Nankathá (**B** 3), but further on the jungle is so dense and trackless that they could not be followed up without

Western scrap of plateau (Sections, I, II, III, Plate 23).

Fossils, Kyaukmo.

elephants; but they apparently form the western scarp of the conspicuous peak Hpataunggyi (3,664 feet), which lies on the strike of the beds (*see* Fig. 3, p. 62).

Northern edge of scrap.

Crossing the plateau from the valley of the Chaung-Magyi to Kalagwé, a large village on the main route from Maymyo to the Ruby Mines, and proceeding northwards, the lower Naungkangyis appear again at the base of the hills two miles north of Tawmawgôn (Loc. 90, **C** 2), where a small outcrop, full of fossils, occurs on the path. The rock is a yellow, soft, argillaceous, fine-grained marl, and the collection made here includes *Heliocrinus* sp.; (?) *Diplotrypa sedavensis* Reed; *Rafinesquina imbrex* Pander; *R. subdeltoidea* Reed; *Orthis testudinaria* Dalman; and *Orthis subcrateroides* Reed. Of these *Rafinesquina imbrex* and *Diplotrypa sedavensis* are Sedaw forms; *R. subdeltoidea*, though allied to *R. deltoidea* Conrad, differs in possessing an internal median ridge in the brachial valve and in ornamentation. It resembles in some respects *Strophomena aranea* Salter, from Niti.[1] *R. deltoidea* is a well-known European and American form of middle and upper Ordovician age. Only detached plates of the cystidean were found, with rhomb ridges and other features which led Mr. Cowper Reed to refer them to the genus *Heliocrinus*, but the species is indeterminable. *Orthis testudinaria* is a well-known and characteristic Ordovician form, ranging from lower Llandeilo to Caradoc, and *O. subcrateroides* resembles, according to Mr. Cowper Reed, *Leptæna cratera* and *L. nux* from the Ordovician of Niti, described by Salter.[2]

Fossils, Tawmawgôn.

Fossils, Chaungzôn.

Along the edge of the plateau, between Tawmawgôn and Chaungzôn, at the head of the Gokteik gorge, the lower Naungkangyi beds are not well exposed, being either overlapped by higher beds, or cut out by faults. At Chaungzôn (Loc. 96, **D** 3), however, near the foot of the cliffs down which the cart road from Nawnghkio is carried by a series of zigzags, to the crossing of the Nám-panhsé, an outcrop very rich in fossils is exposed in a cutting at a sharp turn in the road just below mile 84.[3] The rocks here consist of thin-bedded hard blue lime-

[1] J. W. Salter and H. F. Blanford: Palæontology of Niti (Calcutta, 1865), p. 36, Pl. III, fig. 10.

[2] *Ibid*, pp. 30, 31, Pl. IV, figs. 1, 2.

[3] This is where the old mile-post 85 was placed, as shown on the one inch map. The road between Maymyo and Lashio has been re-measured since the map was published and the present mile-posts do not correspond with their former positions. Those shown on the map will usually be adhered to in describing localities.

stones interbedded with greenish micaceous sandstone, the fossils occurring in the latter. The fauna is particularly rich in specimens of *Orthis* and the whole facies of the deposit is very similar to that in which the Caradoc fossils of Shropshire occur. The collection from Chaungzôn includes *Heliocrinus* sp., the same detached plates that are found at Tawmawgôn, etc.; *Echinoencrinus* aff. *Senckenbergi* v. Meyer; *Orthis calligramma* Dalman; *O.* (*Dalmanella*) *testudinaria* Dalman; *O.* (? *Dalmanella*) *chaungzonensis* Reed; *O.* (*Dinorthis*) *flabellulum* Sowerby; *O. irravadica* Reed; and *O. subcrateroides* Reed.

Detached plates only of the Cystidean *Echinoencrinus* aff. *Senckenbergi* occur, resembling in sculpture and ornamentation those of the type species of the genus from the lower Ordovician of northern Europe. *Orthis calligramma* and *O. flabellulum* are both well-known and characteristic fossils from the Bala or Caradoc beds of Britain. *O. thakil* Salter, from the Ordovician of Niti,[1] is probably allied to *O. flabellulum*. Of the two new species,—*O. chaungzonensis* is allied to *O. argentea* Hisinger, and bears a considerable resemblance to the variety of *O. thakil* from Niti named *subdivisa* by Salter;[2] while *O. irravadica* seems to be closely allied to *O. moneta* Eichw., from the Russian Ordovician.

Nám-non ravine.

To the east of the Gokteik gorge the lower Naungkangyi beds are again concealed for a long distance, being overlapped by higher beds in the valley of the Nám Tang, which joins the Nám-panhsé at Chaungzôn, across the divide which separates this river from the Nám-hsim, and in the valley of the latter river. They reappear however, on the sides and floor of the deep ravine of the Nám-non, a tributary of the Nám-hsim, east of the village of Kunkaw (**E** 2). A few fossils were collected from them at a point on the path leading up from the Nám-hsim to Kunkaw, about a mile south of the village, including *Escharopora* sp., a bryozoan ranging from the Birdseye limestone to the middle of the Cincinnati group of America (middle to upper Ordovician); *Orthis irravadica* Reed; and *Calymene birmanica* Reed, a trilobite resembling very closely *C. parvifrons* var. *Murchisoni* Salter, from the lower Ordovician of England,[3] and in some respects also *C. nivalis* Salter, from the Ordovician of Niti.[4]

[1] Palæont. Niti, p. 39, Pl. IV, figs. 8, 9.
[2] *Ibid*, p. 41, Pl. IV, figs. 11, 12.
[3] Mon. British Trilobites, p. 102, Pl. IX, fig. 26.
[4] Palæont, Niti, p. 10, Pl. I, fig. 24.

Several specimens of *Orthis subcrateroides* Reed and *O. irravadica* Reed were also obtained from a small outcrop of these beds near the village of Umöng (Loc. 98, **E** 2), about a mile south of Kunkaw.

Fossils, Nám-yun.

On the eastern side of the ravine fossils were collected from a band of buff-coloured marly sandstones on the ascent from the stream to Nám-yun (Loc. 99, **E** 2). These included *Rafinesquina imbrex* Pander; *R. subdeltoidea* Reed; *Plectambonites sericea* Sowerby, a characteristic Ordovician species with a very wide horizontal range, commonly known as *Leptæna sericea*; *Orthis irravadica* Reed; *O. subcrateroides* Reed; and *Clitambonites* cf. *squamata* Pahlen, the type of which occurs in the Echinosphærite limestone of the Baltic Provinces.

Nám-Tu George (Section IV, Plate 23).

Beyond this there occurs another gap, in which the lower Naungkangyi beds have not been found, though they probably come to the surface in the deep, trackless valley of the Nám-Sam, since they are found on the Panghsa-pyé saddle (**F** 2), where there is a fairly good exposure at the village. Here they contain *Orthis subcrateroides* Reed, *O. testudinaria* Dalman, and large numbers of the plates of *Caryocrinus* sp. Between this and the valley of the Nám-Tu near Lilu they are concealed or cut out by the great overthrust fault mentioned on page 55, but they reappear in the deep ravines entering the main river from the north-west. A good outcrop was found in the valley of the large stream joining the Nám-Tu at Lilu (Loc. 103, **F** 1), about a mile above the village, and yielded a large number of fossils. The rock here is identical in appearance with that at Chaungzôn, and the fauna is very similar, *Orthis*, especially *O. subcrateroides* Reed, being the most common form. The other fossils collected here included plates of *Heliocrinus* sp. and *Caryocrinus* sp.; *Rhinidictya* cf. *plumula* Salter; *Rafinesquina imbrex* Pander and *R. subdeltoidea* Reed; *Orthis testudinaria* Dalman; *O. irravadica* Reed; *Plectambonites sericea* Sowerby; and fragments of trilobites, consisting of indeterminable, single thoracic segments, some of large size. On the spurs between the ravines the lower Naungkangyis are concealed by higher beds. The most northerly point at which they have been found is in the valley of the Nám-pangyun, between the Bawdwin silver mines and the Nám-Tu, beyond the limits of the map; but no collections of fossils have been made from this locality. Fragments of trilobites are very numerous at particular horizons but are quite indeterminable.

Inliers near Maymyo.

Returning to the vicinity of the railway between Sedaw and Maymyo, the lower Naungkangyis are exposed as inliers in one or two places, being probably brought up by anticlinal folds, though the structure cannot be made out with certainty, owing to the thickness of the jungle. Fossils were collected at the following places:—Lebyaungbyán (Loc. 83, **B** 4), five miles west of Maymyo, at the crest of a ridge immediately west of the village, including *Rhinidictya* sp.; *Phylloporina orientalis* Reed; *Rafinesquina imbrex* Pander; *Leptæna* (?) *ledetensis* Reed; *Chonetes* (?) *thebavensis* Reed; *Orthis testudinaria* Dalman; *Porambonites intercedens* Pander; and *Cyclocrinus* cf. *Spasski* Eichw. Of these *Phylloporina* is a bryozoan ranging from Ordovician to Silurian, and the species described by Mr. Cowper Reed resembles in some respects the Ordovician *Protocrisina exigua* Ulrich, but differs in its mode of growth and other characters. *Leptæna* (?) *ledetensis* is a new species described by Mr. Cowper Reed from the upper Naungkangyi beds of Ledet, three miles north-east of Lebyaungbyán, and its presence here seems to indicate that the horizon of the Lebyaungbyán beds is rather higher in the series than that of the beds hitherto described (*Porambonites intercedens*, *Rafinesquina imbrex*, and *Orthis testudinaria* being the only species found here which also occur in lower beds). In the shape and convexity of the valves and internal characters it resembles the well-known Wenlock and Ludlow fossil *L. rhomboidalis* Wahlenb.

Fossils, Lebyaungbyán.

The presence of *Chonetes* so low down as the Ordovician has not hitherto been recorded, and the reference of the single specimen from Lebyaungby n to it is doubtful. *Cyclocrinus Spasski*, a peculiar organism of somewhat doubtful affinities, occurs in the Ordovician beds of Russia. The rock here is a greenish sandstone, passing into a greenish, granular limestone.

Fossils, Makyinu.

At Makyinu (Machinu) (Loc. 84, **B** 4), about three miles south of Lebyaungbyán, at the head of a steep descent to Sakangyi, the following fossils were collected from a tough, greenish, micaceous sandy shale:—*Protocrinus sparsiporus* Bather, a Sedaw form; *Cheirocrinus* sp.; *Caryocrinus* sp.; *Rhinidictya* cf. *plumula* Salter; (?) *Diplotrypa* sp.; *Plectambonites quinquecostata* McCoy; *Orthis* (*Dalmanella* ?) *chaungzonensis* Reed; and *O. irravadica* Reed. *Rhinidictya* cf. *plumula* is, according to Mr. Reed, comparable with Salter's *Ptilodictya plumula*, from the

Ordovician of Niti,[1] and is apparently allied to *Ptilodictya dichotoma* Portl.

The *Diplotrypa*, as preserved here, at Tawmawgôn, and other places, shows merely the cast of the basal epitheca, the upper part of the fossil being entirely weathered away, and represented by a cavity in the rock. It is one of the commonest fossils in these beds, and occurs in nearly every outcrop. *Plectambonites quinquecostata* is a form recorded from the Ordovician of Britain, Russia, and Australia, and is allied to *Leptæna himalensis* Salter, from the Ordovician of Niti.[2] It also occurs at Ledet.

Hills north of Maymyo.

On the road from Maymyo railway station to the waterworks reservoir, among the hills immediately north of the town, there are several exposures of these beds, but they are not very fossiliferous, and the specimens are greatly crushed, owing to the proximity of a fault along the southern edge of the hills. The only species from this locality (Loc. 92, **C** 4), that Mr. Cowper Reed was able to identify, is *Orthis flabellulum* Sowerby. Another outcrop occurs in the same hills on the path from Naungkangyi to Taungmio (Loc. 91, **C** 4) to the east of the reservoir in the Naungkangyi valley, where *Diplotrypa* (?) sp., *Rafinesquina imbrex* Pander, and *Orthis calligramma* Dalman were obtained. At both these localities the rocks are soft, yellow or buff-coloured, fine-grained marls, greatly crushed and cleaved. The lower Naungkangyi beds were not found at any locality to the south of the railway.

Associated limestones.

The unweathered limestones associated with the lower Naungkangyi beds have not, as a rule, yielded any recognisable fossils, but are composed of an aggregate of somewhat coarsely crystalline grains of calcite and detached stem joints and ossicles of crinoids, or more probably of cystideans, which are visible in great numbers in thin sections of the rock, and sometimes on the natural surface (Plate 11, fig. 1). Their coarsely crystalline character, the absence of dolomite, and the presence of these ossicles serve to distinguish them from the younger limestones of the plateau, which are, as a rule much more fine-grained, are commonly dolomitic, and very rarely contain any traces of organic remains whatever.

[1] Palæont. Niti, p. 46, Pl. IV, figs. 16, 17.
[2] *Ibid*, p. 28, Pl. III, fig. 4*a*—*g*.

Eastern Ranges.

To the east of the Nám-Tu the Ordovician rocks are entirely concealed by the broad band of upper Palæozoic and Mesozoic strata that forms a continuation of the plateau proper extending to the north-east through Lashio towards the Salween. They reappear among the hill ranges east of the plateau, where, as has been remarked before, the rocks are thrown into more or less regular folds, in which the Plateau limestones are included, and the outcrops of the strata exposed by denudation, instead of occurring as isolated patches fortuitously uncovered wherever the burden of overlying rock happens to have been removed, form regular bands, which can be traced in many cases by a mere inspection of the contours of the ridges and valleys for considerable distances. It is not possible, for reasons that have already been given, to follow these bands up continuously on the ground, but the observer can generally predict within fairly narrow limits, by noting the configuration of the ridges and spurs, where each particular formation is to be met with, and by working across the strike, which is usually possible because nearly every spur has a path running along it, can fix their position with considerable accuracy.

Lithological characters and thickness.

The lower Naungkangyi rocks as seen in these ranges present some notable points of difference as compared with their development on the western side of the plateau. The limestones so frequently met with there are entirely absent, and the formation consists of a homogeneous yellow or buff-coloured sandy marl of soft texture, in which the fossils occur as casts, and in so friable a condition that it is only seldom that they can be collected. The most remarkable feature of this band of rock is its persistence in general thickness and character; it is of no great thickness, probably not more than two or three hundred feet, but it occurs in every section wherever the base of the fossiliferous series is exposed, throughout these hills.

Outcrops north of Mongyaw valley.

The most northerly locality at which these beds have been found is on the southern side of the range of hills north of the Nám-yau valley near Mongyaw, a large village on the road from Lashio to the Kunlon ferry. This range lies beyond the limits of the map published with this Memoir, since this portion of the country is not included in the new edition of the quarter inch map issued by the Survey of India. The Naungkangyi beds lie along the axis of an anticlinal fold,

the crest of which has been denuded away, and occupy an elongated oval tract on the southern slopes of the range. Fossils were collected by Mr. Datta at two localities in this area: the first about one and a half miles south-east of Loi-nawk (23° 5′ : 98° 4′), near the western end of the area, and the other one and a half miles north by west of Hoi-hôk (23° 4′: 98° 8′), near the eastern extremity. The fossils are very poorly preserved, but include large numbers of Bryozoa, probably a *Rhinidictya*, of which perhaps more than one species is represented. Other fossils, found at both localities, include plates of *Caryocrinus* and *Heliocrinus* sp., *Diplotrypa* sp., *Rafinesquina imbrex* Pander, *Orthis subcrateroides* Reed, *O. testudinaria* Dalman, (?) *O. irravadica* Reed, and in addition, at the locality north of Hoi-hôk, numerous specimens of *Clitambonites* cf. *squamata* Pahlen, and a doubtful cast of *Porambonites intercedens* Pander. Several casts of the calyx of a simple turbinate coral, resembling *Petraia* (*Lindstrœmia*) also occur here.

Fossils.

Loi-len range (Sections I, II, Plate 24).

Proceeding southwards, the lower Naungkangyis appear from beneath the Plateau limestones at the foot of the Loi-len range on the path running north from Mán-Sé, in the Námma coal-field, to Tileng (Loc. 104, **H** 1). Where first seen they are very poorly exposed, the outcrop being very narrow and nearly vertical, but a few specimens of an *Orthis*, one of which appears to be *O. subcrateroides* Reed, were collected here by Mr. Datta. From this point the band runs diagonally up the side of the scarp to the eastward, and approaches the crest about three-quarters of a mile south of Pang-mé (**H** 1), where it is exposed on the spur running down to the Nám-Pawng valley, on a little saddle connecting the crest with a conspicuous knoll, the latter consisting of the Chaung-Magyi sandstones. It then runs along the hill side parallel to the crest, its course being marked by a ravine, and is found again on the next spur to the east in a similar position, on the saddle just north of the knoll marked 4,744 feet on the one inch map. Hence it continues to the east-north-east, parallel to the crest of the range, which it crosses at the peak marked 5,239 feet, on the path from Loi-len to Na-Nang, and beyond this along the north side of the crest to Panghti (**I** 1), where it crosses again to the south side. Throughout the whole of its course the band is vertical or nearly so, and in places even inverted, dipping at a very high angle to the south and apparently underlying the Chaung-Magyi rocks forming the southern slopes of the range. The fossils that occur in it are

so greatly crushed and distorted as to be in some cases unrecognisable. Beyond Panghti this simple fold appears to be replaced by two or more minor folds, due to a twist in the direction of the main anticlinal, but the ground along the crest of the range is so entirely covered with dense grass jungle that the structure could not be made out exactly. The Plateau Limestone here comes up from the south almost to the crest and arches over the lower Palæozoic rocks, which disappear entirely beneath it a few miles further on, near the village of Tenghkio (**J** 1).

South of Loi-Ling.

The lower Naungkangyi beds do not appear on the southern side of the Nám-Pawng valley, or on the northern and eastern slopes of Loi-Ling, where they are overlapped by higher strata. They are next found along the south-western base of Loi-Ling and are exposed at the point where the cart road from Möng-Yai to Tang-yan enters the hills, about a mile east of the village of Nám-un (**I** 2). Here also they are vertical, greatly crushed, and the fossils are almost unrecognisable. A few miles further to the north-west they disappear beneath the Tertiary silts of the Nám-Sang coal-field, but to the south-east they can be traced for a long distance, forming a narrow fringe along the edge of the Chaung-Magyi rocks which form the core of the range between Möng-Yai and the valley of the Nám-Há.

Valley of the Nám-Há (Section III, Plate 24).

A great fault runs along the valley of this river, bringing down the Plateau Limestone and the rocks beneath it against the Chaung-Magyi series, forming a great mass of interlacing ridges and valleys to the east, and on the west side of this fault there are at least two minor faults which, combined with the folding that has affected all the rocks, have rendered the structure exceedingly complex. The band of lower Naungkangyis can be traced, however, wherever the Chaung-Magyi rocks come to the surface, and can be easily recognised by the fossils, usually by the presence of *Rafinesquina imbrex*, *Orthis subcrateroides*, and *Diplotrypa* sp., which are the most common forms. In one or two localities a hard siliceous rock occurs crowded with casts of a species of *Ctenodonta* or *Nucula*, in which the teeth are well preserved. One of these localities is on the spur running west from the village of Mong-Há to the peak marked 6,055 feet, about three-quarters of a mile below the crest of the ridge (Loc. 110, **I** 3). Another is near the southern extremity of the hills, at the head of a deep ravine cut through Chaung-

Magyi rocks, east of the village of Mán Hpai, on the path to Mong Heng (Loc. 113, **I** 4). Here the *Nuculas* are associated with large numbers of a small *Modiolopsis*, the casts of which cover whole slabs of rock at a particular horizon. Fragments of large trilobites also occur at this place.

Nam-Pang valley.

On the eastern side of the great mass of Chaung-Magyi rocks east of the Nám-Ha valley, the lower Naungkangyi beds are found again, forming as usual a narrow but persistent fringe along the edge of the older series. Near the southern end of this band, in a ravine just north of the village of Nam-tawng, near Pa-tep (Loc. 112, **J** 4), an exposure of the peculiar siliceous rock mentioned above occurs, crowded with casts of *Ctenodonta*, and with them imperfect casts of an indeterminable gastropod, the only specimens of this class that have been found in these beds. A short distance to the south of this locality the whole of the lower Palæozoic rocks disappear beneath the limestones of the plateau, and are not seen again to the south within the limits of the Northern Shan States.

East side of Loi Pan.

Proceeding now in a south-westerly direction across the broad plateau that extends towards Kehsi Mansam in the Southern Shan States, we again meet with the lower Naungkangyi beds along the eastern flanks of the Loi Pan—Loi Twang range, an isolated mass of hills rising like an island from the surrounding plateau. They have not been detected along the western or northern sides of these hills, and are apparently absent along the eastern side also as far as the village of Mán-pun, being probably cut out by a fault or concealed by the Plateau Limestone, which throughout this distance abuts directly against the base of the hills. The Naungkangyi rocks appear first in the bed of the Nám-la, about a mile south-west of Mán-pun (**H** 4), and run across the slopes of the hills to the east of this river, in a southerly direction to the valley of the Nám-hen, about three and a half miles above the village of Ping-hsai. A collection of fossils was made from this band on the slope of the hills south-east of Mán-shio (Loc. 105 **H** 4), about half-way between the village and the peak marked 4,596 feet, including *Diplotrypa* sp.; *Rafinesquina subdeltoidea* Reed; *Orthis subcrateroides* Reed; *O. irravadica* Reed; and *Plectambonites sericea* Sowerby; also an undetermined species of *Hyolithes* and a single specimen of a coiled cephalopod, probably a *Lituites*. Further collections at this locality include the trilobites *Remopleurides*,

Illœnus, *Cheirurus*, *Harpes*, and *Asaphus*, but the species belonging to these genera have not yet been determined.

An outlier of the Ordovician rocks occurs to the west of this band in the valley of the Nám-hen, occupying a synclinal fold in the Chaung-Magyis, and surrounded by a narrow band of the lower Naungkangyi beds.

East side of Loi Twang.

A fault runs along the valley of the Nám-hen, truncating the little synclinal just mentioned, and shifting the Mán-pun band of lower Naungkangyis to the eastwards. It is found again on the south bank of the river at a point where the latter makes a sharp bend to the south about two miles above the village of Ping-hsai (**H** 4), whence it extends to the south-south-east, across the flanks of Loi Kôk, to the village of Hwe-wá (Loc. 107, **H** 5), three miles west-north-west of the town of Kehsi Mansam, where another fault occurs, shifting it westwards again for about the same distance as the Nám-hen fault does. It then continues in the same direction, along the base of the Loi Twang range, its course being marked by a series of narrow valleys and depressions, through the village of Hwe-Mawng (**H** 5) to the eastern side of the Loi Pamong ridge. Its southerly extension has not yet been traced beyond this.

Fossils.

Fossils of the same species as those enumerated above from near Mán-shio may be found wherever an outcrop occurs, but they are as usual greatly distorted and crushed, and the beds are in most cases either vertical, or tilted up at high angles, and in some places even inverted. Among these fossils the new trilobite *Calymene birmanica* has been detected by Mr. Cowper Reed in a small collection from Loi Kôk (Loc. 106, **H** 5), and the brachiopod *Orthisina ascendens* Pander in that from the flanks of Loi Pamong (Loc. 108, **H** 5); this is a lower Ordovician form from the Kuckers beds of the Baltic Provinces.

Conditions of deposition.

Although the lower Naungkangyi beds have been found to rest directly upon the unfossiliferous rocks of the Tawng-Peng system wherever the line of contact is exposed, and the unconformity between them is usually well marked, no traces whatever of conglomerates, or even of sandstones, coarse or fine-grained, are met with among them, nothing, that is to say, which implies the presence of dry land in the immediate neighbourhood at the time of their deposition. They appear to have been laid down in the open sea, perhaps in a sea of not very

great, but uniform depth, judging from the homogeneous character of the deposits over wide areas. The presence of the Ngwetaung sandstones, and of bands of limestone in the western portion of the area occupied by these deposits, and their greater thickness in that direction, seem to indicate that the coast-line lay to the westward; and this conjecture appears to be the more probable, because no deposition seems to have taken place over the area occupied by the crystalline rocks to the north-west of the Shan States, throughout the whole of the Palæozoic and Mesozoic periods.

Age.

Consideration of the homotaxial equivalents of the lower Naungkangyi beds in other regions of the earth's surface will be deferred until the whole of the group has been described, but sufficient has already been said to indicate that they correspond very closely with the middle Ordovician rocks of the Baltic Provinces.

Upper Naungkangyi Stage (Western Area).

Lithological characters.

The strata now to be described have a very much wider distribution at the surface than the lower Naungkangyis, and may be said to constitute, after the Plateau limestone, the most important formation occurring in the Shan States. They consist of peculiar argillaceous shales and claystones often resembling lithomarge in texture, and present a great variety of colours, ranging from red through lavender, orange, and various shades of yellow to a pure white. In all cases they bear evidence of intense crushing, which has resulted in the development of a kind of incipient cleavage, resulting, in many cases, in the obliteration of the original bedding planes, so that the term 'shales' hardly describes them correctly. The rock, indeed, often presents the appearance of a mass of clay that has been passed through a 'pug mill'; and when broken by the hammer, the fracture has some resemblance to a 'slickensided' surface. This compression has of course resulted in a general distortion of the fossils, as in the lower Naungkangyi beds.

Two types of strata.

Two lithological varieties of these beds have been distinguished, one of which is found along the southern and eastern borders of the old Tawng-Peng land surface, comprising all the beds of this age to the west of Lashio, which are of the variegated type described above; while the second is the predominating type in the Eastern ranges, consisting

mainly of bright purple claystones. In the western area a precisely similar purple band occurs at the top of the variegated Naungkangyi shales, and though only a few feet in thickness, is very conspicuous by reason of its dark colour, and very persistent over a wide area. In mapping the country, I thought at first that there were peculiarities in the fauna of this purple band which were reproduced throughout the purple beds of the eastern area, and I therefore gave the latter a separate name, that of the Hwe-Mawng beds, from a village where I hit upon a very rich assemblage of fossils, 7 miles to the west of Kehsi Mansam. During the progress, however, of the last field-season's work in the Shan States, 1906-07, Mr. Coggin Brown and I collected from the variegated shales below the horizon of the purple band, at a locality near Lilu in the Nám-Tu valley, a number of trilobites which seem to be identical with those from Hwe-Mawng, and it is therefore quite likely that the purple beds of the east represent the whole of the upper Naungkangyis of the west. The fossils from both areas have been sent to Mr. Cowper Reed for identification and description, but he has not yet had time to work them out. He has, however, kindly furnished me with a preliminary list of them, but the specimens cannot be said to possess the same value in fixing the horizon of the beds as those whose description has already been published. His provisional determinations are therefore marked in the list given below by the sign P; while new forms are printed in heavy type, and the asterisk* signifies those which also occur in the lower Naungkangyis. At the same time I think it advisable to retain the separate names for the present, since it is not yet certain how far the beds as developed in the two areas correspond with each other.

Hwe-Mawng beds.

Upper Naungkangyi Fossils (Western Area).

Anthozoa :—
- P. *Favosites* sp.

Cystidea :—
- * *Echinoencrinus* cf. *angulosus* Pander
- * ,, aff. *Senckenbergi* E. v. Meyer
- *Cryocrinus* sp.
- P. *Heliocrinus* sp.

Bryozoa :—

(?) *Escharopora* sp.
Phylloporina sp.
Diplotrypa **palinensis** Reed
*P. *Rhinidictya* cf. *plumula* Salter
P. *Monticulipora* sp.
P. New Bryozoan (gen. indet.)

Brachiopoda :—

Rafinesquina* **subdeltoidea Reed
Leptæna* **ledetensis Reed
**Plectambonites* *quinquecostata* McCoy
,, *repanda* Salter
* ,, **sericea** Sowerby
**Orthis* (*Dinorthis*) *flabellulum* Sowerby
* ,, **irravadica** Reed
**Clitambonites* cf. *squamata* Pander
P. *Scenidium* sp.
*P. *Orthisina* cf. *ascendens* Pander
P. *Porambonites* sp.
P. *Lingula* sp.
P. *Strophomena* (?) sp.

Mollusca :—

P. *Ctenodonta* 2 sp.
P. *Modiolopsis* sp.
P. Lamellibranch (gen. indet.)
P. *Pleurotomaria* (?) sp.
P. *Trocholites* (?) sp.

Arthropoda :—

Remopleurides sp.
Encrinurus sp.
Pliomera **ingsangensis** Reed
Calymene* **birmanica Reed
Sphærocoryphe sp.
P. *Illænus* sp. nov.
P. *Asaphus* (*Ptychopyge*) sp. (aff. *radiatus* Salter)
P. *Cheirurus* sp.
P. *Lichas* sp.
P. *Bronteopsis* (?) sp. nov.

P. *Ampyx* sp. nov.
P. *Phacops* (*Pterygometopus*) sp. (aff. *alifrons* Salter)
P. *Harpes* sp.
P. *Agnostus* sp. nov.
P. *Primitia* sp.

Hwe-mawng Fossils (Eastern Area).

Bryozoa :—

P. *Ptilodictya* (?) sp.

Brachiopoda

P. *Christiania tenuicincta* (?) McCoy
P. *Strophomena* aff. *corrugatella* Dav.
P. *Orthis* (*Dalmanella*) sp.
P. *Plectambonites* (?) sp.

Mollusca :—

P. Lamellibranch (gen. indet.,
P. *Straparollus* (?) sp.
P. Large gastrogod (gen. indet.)
P. *Hyolithes* sp.
P. *Bellerophon* (*Sinuites*) sp.

Arthropoda :—

P. *Asaphus* (*Ptychopyge*) sp. No. 1 (aff. *Lawrowi* Schm.)
,, ,, sp. nov. No. 2
P. *Ampyx* sp.
P. *Dionide* (?) sp.
P. *Phacops* (*Pterygometopus*) sp. nov. (aff. *Panderi* Schm.)
P. *Illænus* sp.
P. *Calymene* aff. *duplicata* Murch.
Pliomera ingsangensis Reed

Profusion of organisms.

Although the collection made from these beds is not as large as it might have been, on account of the fragmentary state of most of the specimens met with, the number of individual organisms that flourished in the seas of this period must have been extraordinary. It is seldom that one breaks open even a small piece of the rock without exposing at least the stem joint of a crinoid or cystidean, and detached plates of the calices of the latter are almost as common. The ornamentation of the plates and the minutest details of the pore-rhombs, etc., are

usually beautifully preserved in these casts, when first exposed, but they are in so soft a condition that the slightest touch will destroy them, and the greatest care is required to preserve the specimen. Detached eyes of trilobites are also very common in some places, showing the details of the lenses in great perfection, but in the same soft condition, though the other parts of the animal are generally more solid and capable of being preserved in a collection.

Distribution. Western scarp of plateau.

On the western side of the plateau these beds occupy a large area, extending northwards from a line drawn along the base of the hills north of Maymyo to the head of the Sedaw valley near Sakangyi, (B 5) as far as the Memauk-Aunglôk spur. Throughout this area the beds, as seen in numerous outcrops, are generally tilted up at high angles, or are vertical, and it seems at first sight as though the formation must be of very great thickness; but where it is exposed on the face of the great 2,000 feet scarp north of the Memauk spur, it is seen to be at the most from 700 to 1,000 feet thick, and it appears possible that the prevalence of high dips in the southern part of the area is due either to 'creep' along the steep hill sides; to weathering out of the 'cleavage' lines; or, what is more likely to be the true explanation, to a general compression of these soft strata between the harder rocks under and overlying them into a series of minor folds and contortions, which cannot be recognised as such on the ground because of the small extent and superficial character of the outcrops.

Great apparent thickness.

Fossil localities.

In this area collections of fossils were made at the following places:—At the head of the Sedaw valley, on the path from Ani Sakan railway station to Sakangyi (Loc. 85, **B** 5), besides cystidean plates, a doubtful specimen of *Escharopora* sp. was obtained. Further east, at the top of a small hill immediately north of the village of Nankat, near Letkaung (**B** 4), *Plectambonites sericea* Sow. and *Orthis irravadica* Reed, both lower Naungkangyi forms, were the only two recognisable fossils collected; but a short distance further to the north-east, near the village of Ledet (Loc. 82, **B** 4), in some lavender coloured shales, *Leptæna* (?) *ledetensis* Reed, already recorded as occurring at Lebyaungbyán (p. 77), *Plectambonites quinque-ostata* McCoy, *Orthis irravadica* Reed, and two trilobites, *Remo-*

pleurides sp. and *Pliomera ingsangensis*, a new form described by Mr. Reed, were found. The *Remopleurides* is a unique specimen, and is not in a very satisfactory state of preservation, but "most of the characteristic generic features are visible." The Ledet specimen, according to Mr. Reed, is allied to *R. Colbii* Portlock, from the Caradoc beds of Co. Tyrone in Ireland. *Pliomera ingsangensis* is the most common trilobite in the upper Naungkangyi beds, and the detached pygidia occur at a large number of localities; specimens of the thorax and carapace are not so frequently found. The pygidia are often very minute, and require to be carefully looked for.

The genus, more commonly known as *Amphion*, is exclusively Ordovician, and has a wide geographical range, occurring in Bohemia as well as in Russia, Britain, and America. The species described by Mr. Reed resembles in the characters of the head *Pl.* (*Pliomerops*) *canadensis* Billings, but the pygidium agrees more closely with *Pl. Fischeri* Eichw., a Baltic species. A pygidium described by Salter[1] from the Ordovician of Niti resembles the Burmese form so closely that Mr. Reed is convinced that they are identical, but he thinks that there is insufficient evidence for attributing this pygidium to the head-shield described by Salter as *Cheirurus mitis*, for not only are the material in which the head-shields and pygidium occur, and their mode of preservation, quite distinct, but the pygidium is not of a *Cheirurus* type, no species of that genus being known to possess more than four pairs of pleuræ, whereas both the Burmese species and the Niti specimen figured by Salter have five.

On the path from Maymyo to Naungkangyi village, where it crosses the hills north of the railway station, numerous plates of *Caryocrinus* sp. were found, also another cystidean, *Echinoencrinus* cf. *angulosus* Pander, a Russian form from the 'Vaginatenkalk' (lower Ordovician) near St. Petersburg. Specimens of *Orthis irravadica* and *Pliomera ingsangensis* Reed may also be found here, on the slopes of the hills facing Naungkangyi (Loc. 92, **C** 4).

Ngá-pwe-sôn valley.

To the south of the railway the upper Naungkangyi beds cover a large area in the valley of the Ngá-pwe-sôn stream, to the east of the ridge bordering the Maymyo cart road between Pyinthá and Zegôn, extending from

[1] Palæont. Niti, p. 6, pl. 1, figs. 18,18*a*.

Thabyegôn almost down to the Nám-Tu, or Myitngé as it is called in this part of its course, at Lema. All round the sides of this valley the Plateau Limestones rest directly upon them, the intervening Silurian beds being absent; on the west side the latter are probably cut out by a fault. A few fossils were obtained on the ridge a short distance west of Kunlein, (Loc. 89, **B** 5), on the path from that village to Pyintha, including *Echinoencrinus* aff. *Senckenbergi* v. Meyer, already mentioned as occurring in the lower Naungkangyis of Chaungzôn, (p. 75); *Phylloporina* sp.; *Clitambonites* cf. *squamata* Pahlen, also a lower Naungkangyi species; and *Pliomera ingsangensis* Reed. A patch of these rocks also occurs further west, between Naungwai and Lungaung.

Kyauk-kyán scrap.

The only other locality south of the railway at which these beds have been observed is at the southern end of the great scarp crossed by the railway between Hsum-Hsai and Nawnghkio at Kyauk-kyán (**D** 3). As one descends the steep grade leading down to Wetwin station, on the journey from Maymyo to Hsipaw, this scarp closes the view to the east, rising like a wall beyond the broad valley of the Ke-laung and Hpawng-aw streams, surmounted by precipitous cliffs of limestone. The scarp is due to a fault, which runs along the base of it, increasing in throw from north to south, and this becomes so great near the southern end, that the formations underlying the Plateau Limestone are brought to the surface, the upper Naungkangyi beds being exposed on the face of the scarp, to a thickness of about 300 feet, on the path from Hkelawng village to Enghpo, and containing the usual fossils (Loc. 97, **D** 4).

Northern edge of Plateau.

Along the northern edge of the plateau the upper Naungkangyis are exposed continuously from Nanyòk (**C** 2), near Kalagwé, in a south-easterly direction to Pamôn, on the Nám-panhsé. Here there is a gap, apparently due to a fault running along the bed of the river, probably a continuation northwards of the Kyauk-kyán fault mentioned in the last paragraph; but they appear again on the left bank, on the slopes below Pangsông (**D** 3). They are not well seen at Chaungzôn, but may be found along the cart road near the river between the lower Naungkangyi locality (p. 74) and the bridge. Beyond this they are concealed by overlap along the valley of the Nám-Tang to the

bend from north to west near Mán-Loi (**D** 3), west of Pyaunggaung station. Here they reappear on the right bank of the river, and are fairly well exposed at Hweyawt (Loc. 95, **D** 3), where *Pliomera ingsangensis* is very common, as well as plates of *Caryocrinus* sp. Hence they continue up the right bank of the Nám-Tang to the bend north of Nám-saw, and are found on the lower slopes of the hills north of this village, on the zig-zags of the cart road leading to Möng-Lông (Loc. 94, **D** 2). At this locality there has been a great deal of faulting and other disturbance of the strata, and it is by no means easy to make out their relations with each other.

Fossils, Ingsang.

Between this point and the ravine of the Nám-non, east of Kunkaw, the upper Naungkangyi beds are exposed only in patches, as inliers surrounded by higher formations. One of these occurs in the ravine immediately south of Kiohsiô (S) (**E** 2), and extends across the ridge west of that place to the site of the deserted village of Ingsang (Loc. 93, **D** 2), which has given its name to the little trilobite *Pliomera ingsangensis,* so common in these beds. Besides this species, the fossils collected here included *Rafinesquina subdeltoidea* Reed, *Plectambonites sericea* Sow., *Encrinurus* sp., and *Sphærocoryphe* sp., as well as numerous plates and the detached arms of cystideans. Only single and very minute specimens of the other two trilobites were found, that of *Encrinurus* being a pygidium only 2 mm. in length ; while *Sphærocoryphe* is represented by a cast and impression of a head-shield about 4 mm. in length. Mr. Reed compares it with *Sph. Hubneri* Schmidt, from Stage C 3 of the Ordovician of the Baltic Provinces. The genus appears to be confined to the northern marine zoogeographical provinces in Europe.

Nam-Tu valley.

The upper Naungkangyi beds occur in the deep ravine east of Kiohsiô leading down to the Nám-hsim, but the sides of the ravine are so densely clothed with jungle that it was found impossible to trace the boundaries of the formations with any degree of accuracy here. They are overlapped by higher beds in the gorge of the Nám-hsim, but are found on both sides of the Nám-non ravine, about Kunkaw on the west and Nám-yun on the east. They appear again on the Panghsa-pyé saddle, and from this point may be traced almost continuously down to the gorge of the Nám-Tu. They are very well exposed on the spurs to the west of the river and in the bed of the river itself, and large collections of fossils

have been made from them at various places, namely :—At Lilu; on the path from this village to Mán-Ping (Loc. 102, **F** 1), which runs almost entirely over them; at Tá-pangtawng ferry (Loc. 101, **F** 1); on the spurs above this village, near Ngai-tao and between the latter place and Mán-ngai (Loc. 100, **F** 1). The fossils collected from these localities have not yet been worked out in detail, but according to Mr. Cowper Reed's provisional list those from near Lilu include an *Asaphus* allied to *A.* (*Ptychopyge*) *radiatus* Salter, a Caradoc form; species of *Illœnus*, *Cheirurus*, *Lichas*, *Bronteopsis*, and *Ampyx*, all well-known Caradoc or Llandeilo genera, as well as the two new species *Pliomera ingsangensis* and *Calymene birmanica* already described by Mr. Reed in his Memoir, and a species of *Primitia*. The brachiopoda found here include species of *Scenidium*, *Plectambonites*, and *Orthis*, while *Hyolithes* is very common. Further up the valley too, near Mán-ngai and at Tá-pangtawng, a similar collection was made, including, at the former locality, a *Phacops* allied to *P.* (*Pterygometopus*) *alifrons* Salter, another Caradoc form, and a species of *Harpes* at Tá-pangtawng.

Limestone bands.

Along the river bed above Lilu strong bands of limestone are found, apparently intercalated among the shales. These, however, are probably only lenticular masses with a quite local development. They do not appear on the west side of the river, and are absent in the section on the Nám-pangyun below Bawdwin, beyond the limits of the map.

Upper Naungkangyi Stage (Eastern Area).

Purple beds of Hwe-Mawng.

Purple shale band.

In all the outcrops of the upper Naungkangyi beds exposed to the east of the Gokteik gorge, there occurs at the top of them a narrow band of dark purple shales, already alluded to on page 85, often so calcareous as to become an impure argillaceous limestone. When this is the case the rock has an almost schistose appearance, so much so that it has actually been described as a micaceous schist, the calcareous matter occurring in the form of lenticular "eyes," resembling the drawn-out crystals of felspar in an 'augen' gneiss. The more argillaceous portions of the rock are highly fossiliferous, containing large casts of fragments of crinoid stems, cystidean plates, etc., but except a few trilobites, and those not well preserved, no determinable fossils have been collected from this band. It has not been

detected anywhere to the westward of the Gokteik gorge, where it is found at the eastern end of some of the zig-zags on the cart road, and at the bridge in the bed of the gorge, but to the eastward, as far as the rocks have been traced up the Nám-Tu valley, it is very persistent, though not more than a few feet thick.

Lithological characters.

Among the ranges east of the plateau the lower Naungkangyi beds are followed immediately by a great thickness of purple rocks resembling very closely this narrow band at the top of the upper series. The variegated shales of the western area are absent here, but since the purple beds contain similar fossils, especially *Pliomera ingsangensis*, which seems to be pretty freely distributed throughout, and is especially common near the base of the formation, I think there is little doubt that these eastern beds are the equivalents, in point of time, of the whole series in the west, including the variegated shales and the purple zone, and that the difference in colour is due to accidental causes. These rocks are seldom calcareous, but possess a peculiar texture, resembling that of the mudstones of the Ludlow formation in England, with, as commonly happens in the latter rocks, a tendency to become aggregated into nodular concretions. They often exhibit no well defined bedding planes, and break with a somewhat conchoidal fracture; perhaps the term 'claystone' is the one that best expresses their peculiar character.

Distribution. Loi-len range.

The purple beds are found all along the crest of the Loi-len range east of Lashio, conforming everywhere to the distribution of the lower Naungkangyi band beneath them, but they are not developed to the same extent as they are further south, nor were they found to contain any fossils worth collecting, probably because of the intense crushing they have sustained. In some places, as on the pass near Loilen village (Loc. 109, I 1), the pressure has been so great that the beds resemble a schist rather than a shale, and were it not for their position, and the traces of organisms which they still contain, they might be taken for much older rocks.

Mong Keng dome.

To the east of the broad plateau stretching eastwards from the base of Loi Ling, in which the Tertiary coal-field of Mán-se-lé, described by Mr. R. R. Simpson,[1] is situated, rises an elongated dome-shaped mass of

[1] The Námma, Mán-sang and Mán-se-lé Coal-fields, Northern Shan States, Burma; *Records, Geol. Surv. Ind.*, Vol. XXXIII, Pt. 2, p. 152.

hills separating this part of the plateau from that of the sub-State of Mong Keng, extending towards the Salween. The whole of the central portion of this mass of hills, forming an oval area measuring 11 miles from north to south, and 4 from east to west, consists of these purple beds, brought up by a dome-shaped anticlinal.

The formation here must be of great thickness, for though the hills are deeply eroded, and the beds are tilted up at fairly high angles, no indication of the lower Naungkangyis or any other rocks at the base has been detected. The purple beds are full of crinoid fragments, and the detached eyes of trilobites are common enough, but no well preserved fossils were found in this area.

Base of Loi Ling.

The purple beds are also exposed along the south-eastern flanks of Loi Ling, round the head of the Nám-Pat valley. The thickness exposed here is not so great, either because they are overlapped by higher beds, or perhaps because there was some original thinning out against the platform of older rocks now forming Loi Ling. The purple beds here rest directly upon these older rocks, the lower Naungkangyis being absent or overlapped.

Hills east of Möng Yai.

Among the hills east of Möng Yai, on the western side of the Nám-Há valley, these beds cover a very wide area. The western slopes, from the point where the Tang-Yan cart road crosses the hills north of Möng Yai, to Mán-Hpai at the southern end of the range, are almost entirely composed of them, and on the other side of the main ridge they extend from the head of the Nám-Há river to Mong Heng, where it debouches on to the plateau.

Fossils.

Fossils abound in the rocks at many places, and outcrops are numerous in the many deep ravines that score the hill sides. Collections were made at about a mile south-west of Hkawnh-kôk (Loc. 75, **I** 3), on the path leading across the hills from Náwa to Mán-Hpai, where a species of *Asaphus*, an *Orthis* (*Dalmanella*) and *Hyolithes* are very common; at Hwe-hôk (Loc. 76, **I** 3), about half-way between Nawá and Mong-Há, where fairly well preserved specimens of a species of *Ampyx*, and a single one of a *Trinucleus*-like form, probably a *Dionide*, with the ubiquitous *Hyolithes*, were obtained; and in a ravine about half a mile west of Mong-Há (Loc. 77, **I** 3), on the path leading up to the peak marked 6,055 feet. Here the collection included, besides the genera mentioned above, specimens of a *Phacops* (*Pterygometopus*)

allied to *P. Panderi* Schmidt, and belonging to a sub-genus of the *Phacopidæ* strictly confined to the Ordovician; a *Strophomena* allied to *S. corrugatella* Davidson, confined in England to the Llandeilo and Caradoc formations, but ranging in Scotland to the middle Llandovery; and a brachiopod which Mr. Cowper Reed thinks resembles *Christiania tenuicincta* McCoy, also a Caradoc form. Near the head of the Nám-Há (Loc. 74, **I** 3) I found a single specimen of a large *Bellerophon* (*Sinuites*) in these beds, and on the roadside near Kanlún, a mile south of Hwe-hôk, Mr. Coggin Brown picked up a distinctly preserved specimen of *Agnostus*, the only one of this genus that has so far been found. The fragment in which it occurs was unfortunately not *in situ*, however, and the horizon from which the specimen originally came is doubtful.

Nám-Pang valley.

On the eastern slopes of the hills east of the Nám-Há, facing the broad valley of the Nám-Pang, another wide band of these purple rocks occurs, and small collections were made at two places: on the path from Nampung to Nawng-yün (Loc. 78, **J** 3), near the head of a small ravine about a mile east of the latter village, where the pygidia of *Pliomera ingsangensis* Reed were found in considerable numbers in a bed low down in the series, together with as yet undetermined species of *Asaphus* and *Phacops* (*Pterygometopus*); and near Hsophi (Loc. 79, **J** 4), close to the southern end of the band, where the collection made includes *Asaphus* (*Ptychopyge*) sp. (aff. *Lawrowi* Schm.), *Christiania tenuicincta* (?) McCoy, and species of *Hyolithes* and (?) *Ptilodictya*.

East side of Loi Pan and Loi Twang.

The purple beds are again well developed along the eastern side of the Loi Pan range, extending from the valley of the Nám-Lá, between Mán Pun and Möng-Lá, to that of the Nám-hen west of Ping-hsai, the whole of this mass of hills to the east of the lower Naungkangyi band being composed of them. The thickness exposed must be very great, though it is impossible to measure it on account of the numerous folds into which the strata have been thrown. South of the Nám-hen the purple beds continue across the flanks of Loi Kôk, shifted to the east by the transverse fault along the valley of the Nám-hen, and occupying all the ground up to the valley of the southern branch of that river. They are then thrown back to the west by the Kehsi Mansam fault, and form all the foot-hills parallel to the Loi Twang range as far

as Loi Pamong, beyond which point they have not yet been followed.

Fossils.

Fragmentary remains of fossils are commonly met with throughout this band of rocks, but only at one point were they found to be worth collecting. This was at Hwe-Mawng (Loc. 73, **H** 5), a village at the foot of Loi Twang, 7 miles west of Kehsi Mansam. Here the fossils occur quite low down in the formation, within 100 feet or so of the lower Naungkangyi band, which passes through the village. Well preserved specimens of large trilobites are fairly common, including, according to Mr. Cowper Reed's provisional determination, two new species of *Asaphus*, one allied to *A.* (*Ptychopyge*) *Lawrowi* Schmidt, a characteristic Kuckers form; a new species of *Phacops* resembling *P.* (*Pterygometopus*) *Panderi* Schmidt; a *Calymene* allied to *C. duplicata* Murchison, both characteristic Llandeilo species; with *Plectambonites* (?) sp., *Straparollus* (?) sp., and two new species of *Hyolithes*, a very common fossil here. Since these were the first recognisable fossils that I obtained from the purple beds, I have bestowed the name of this village on the formation.

West side of Loi Pan.

A small, isolated area of the purple beds was discovered by Mr. Coggin Brown on the western side of the Loi Pan range at Mán-sam-lai, on the cart road from Möng Tung to Hsipaw, measuring about 4 miles from north to south, by about one mile in breadth.

Age.

In his Memoir on the lower Palæozoic fossils of the Northern Shan States, Mr. Cowper Reed has already discussed the palæontological evidence for the age of the Naungkangyi formation, and has established the fact of its general correspondence with some part of the Ordovician system in Europe and North America. Since, however, the fossils as sent to him were labelled as having been collected from one set of beds, and it was not until afterwards that further work in the field showed that he was justified in assuming that more than one stage was represented, he was obliged to rest content with this general expression of opinion, and to defer a more definite correlation of

the formation with its equivalents in other regions until more was known about the stratigraphical conditions actually prevailing in the field.

Review of palæontological evidence.

Although much remains to be done in working out the details of the stratigraphy,—the determination, for instance, of the exact horizon of the unique, though richly fossiliferous, Cystidean beds of Sedaw being still uncertain,—the division of the formation (leaving out of account for the present the Ngwetaung sandstones, which have so far not yielded any determinable fossils) into two easily distinguished groups, a lower and an upper, has been established; and I propose to review the palæontological evidence placed at our disposal by Mr. Cowper Reed's able Memoir, in the light of the more complete stratigraphical knowledge we possess.

Range and distribution of species.

In order to make this evidence more clear, it will be convenient to arrange the fauna described from each division of the formation respectively in tabular form, giving the stratigraphical position of each genus and species, or its nearest allies, as it has been determined in other regions. In these tables new species are printed as before in heavier type, and those which are found in both the upper and lower stages of the formation are marked with an asterisk :—

TABLES 2 AND 3.

List and Distribution of Naungkangyi Fauna.

TABLE 2.

List and Distribution of

NOTE:—The following abbreviations are used in Tables 2 and 3:—
Lw = Ludlow.
Wk = Wenlock = Étage E2, *Bohemia* = Niagara Group, *N. America.*
Ly = Llandovery = Étage E1, *Bohemia.*
Cc = Caradoc or Bala = Wesenberg beds, *Russia* = Trinucleus and Brachiopod beds, *Sweden* = Étage D4, D5, *Bohemia,* = Trenton Group, *N. America.*

NAME.	RANGE AND DISTRIBUTION OF GENERA.
CYSTIDEA.	
Aristocystis **dagon** Bather	U. Ord., Bohemia . . .
Heliocrinus **fiscella** Bather	U. Ord., N. Europe, Bohemia, S. France.
„ **rugatus** Bather	Ditto . . . .
„ **qualus** Bather	Ditto . . . .
„ sp.	Ditto . . . .
Caryocrinus **aurora** Bather	U. Ord., Scandinavia. Sil., America

Lower Naungkangyi Fauna.

Lo = Llandeilo = Echinosphærites beds, *Russia*=Étage D2, D3, *Bohemia*.
Ag = Arenig = Vaginaten limestone, *Russia* = Orthoceras limestone, *Sweden* = Chazy Group, *N. America*.

Sil=Silurian ; Ord. = Ordovician.

U. = Upper ; M. = Middle ; L. = Lower.

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally.					Remarks.
	Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	
A. bohemicus Barr.	..	..	..	Cc	..	
H. balticus Eichw.	L.Lo	..	..	..	..	
H. aranea Schloth	L.Lo	..	..	..	..	
H. Helmhackeri Barr.	..	..	..	Cc	..	
H. Rouvillei v. Kœn.	..	..	..	..	..	Cc, S. France.
H. confortatus Barr.	..	..	..	Cc	..	
H. granatum Wahlenb.	..	Ag	..	..	..	
—		..	..	..	..	
C. ellipticus Miller and Gurley.	..	..	..	..	Wk	

TABLE 2—*contd.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
CYSTIDEA—*contd.*	
Caryocrinus turbo Bather	U. Ord., Scandinavia. Sil., America.
avellana Bather	Ditto . . . .
,, (?) sp.	Ditto . . . .
Protecrinus sparsiporus Bather	L.-M. Ord., Russia, U. Ord., Bohemia.
*Echinoencrinus aff. Senckenbergi H. v. Meyer .	Ord., N. Europe . . .
Cheirocrinus (?) sp.	Ord., Europe, Canada . .
BRYOZOA.	
Escharopora sp.	M-U. Ord., Europe, America .
*Rhinidictya cf. plumula Salter	U. Ord., Himalaya, Europe, America.

Lower Naungkangyi Fauna—*contd.*

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally.					Remarks.
	Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	
C. bulbulus Miller and Gurley.	..	..	..	.	Wk	
C. sphæroidalis Miller and Gurley.	..	..	..	..	Wk	
—	..	..	..	..	..	
—	..	..	..	..	..	(?) *Hemicosmites Loczyi.* Pupjao S. W. Yunnan.
P. fragum Eichw.	L. Lo	..	..	Cc	..	
—	L. Lo	..	..	..	..	
—	..	..	..	..	..	
—	..	..	..	..	..	
Ptilodictya plumula Salter.	..	..	..	..	..	Cc, Niti Pass.
Ptilodictya dichotoma Portl.	..	..	Cc.	..	..	Ireland.

TABLE 2—*contd.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRYOZOA—*contd.*	
Rhinidictya sp.	U. Ord., Himalaya, Europe, America.
Phylloporina orientalis Reed.	Ord-Sil., America . . .
" sp.	Ditto . . . .
Diplotrypa (Mesotrypa) sedavensis Reed . .	Ord., N. Europe, America . .
" " (?) sp.	Ditto . . . .
" (?) sp.	Ditto . . . .
Fistulipora sp.	Sil-Perm., Europe, America .
BRACHIOPODA.	
Schizotreta cf. elliptica Kut.	Ord.-Sil., Russia, N. America .
Rafinesquina imbrex Pander.	Ord., Europe, N. America . .

Lower Naungkangyi Fauna—*contd.*

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally. Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	Remarks.
R. mutabilis Ulrich	..	..	..	..	Cc	
R. paupera ,,	..	..	..	..	Cc	
Protocrisina exigua Ulrich.	..	..	..	..	Cc	
Ph. corticosa Ulrich .	..	..	..	..	Cc	
Mesotrypa Whiteavesi Nich.	..	..	..	..	Cc	
Mesotrypa regularis Foord.	..	..	..	..	Cc	
—	..	..	..	..	..	
—	..	..	..	..	..	
—	..	..	..	..	..	
—	Ag	..	..	..	..	
Strophomena imbrex Pander.	Ag	..	..	..	..	
Strophomena lineatissima Salter.	..	..	..	..	..	Cc, Niti Pass.

TABLE 2—*contd.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRACHIOPODA—*contd.*	
Rafinesquina **subdeltoidea** Reed . . .	— . . . . .
*Plectambonites quinquecostata McCoy . .	Ord.-Sil., Cosmopolitan . .
* ,, sericea Sow.	Ditto . . . . .
Orthis calligramma Dal.	Ord.-Carb., Cosmopolitan . .
,, (Dalmanella) testudinaria Dal. . . .	Ord.-Dev., Cosmopolitan . .
,, (,,) elegantula Dal. . . .	Ditto . . . . .
,, (,, ?) **chaungzonensis** Reed . .	Ditto . . . .

Lower Naungkangyi Fauna—*contd.*

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally.					Remarks.
	Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	
—	..	Ag	Lo-Ly	..	..	Sil., Australia.
Leptæna himalensis Salter.	..	..	..	..	..	Cc, Niti Pass.
—	Lo-Cc	..	Lo-Ly	..	..	Cc, Niti Pass. L.Ly., Kian Tschang pa, China.
—	Lo	..	Lo-Ly	..	..	L.Ly, Kian Tschang pa, China.
—	Lo-Cc	..	Lo-Cc	Cc ?	Cc	Cc, Niti Pass.
—	Cc	..	Lo-Lw	Ly-Wk	Wk	Sil., Australia.
O. argentea His	..	Cc	..	..	..	
O. thakil var. *subdivisa* Salter.	..	..	..	..	..	Cc, Niti Pass.

TABLE 2—*concld.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRACHIOPODA—*concld.*	
*Orthis (Dinorthis) flabellulum Sow.	U. Ord., Europe. Sil., America
„ **irravadica** Reed	Ditto
„ **subcrateroides** Reed	—
Chonetes (?) **thebavensis** Reed	Sil.-Carb., Cosmopolitan
Clitambonites cf. pyron Eichw.	Ord., Europe, America
„ cf. squamata Pahlen	Ditto
Porambonites intercedens Pander	Ord., Cosmopolitan
ARTHROPODA.	
*Calymene **birmanica** Reed	Ord.-Sil., Cosmopolitan
INCERTÆ SEDIS.	
Cyclocrinus Spasski Eichw.	U. Ord., Russia

Lower Naungkangyi Fauna—*concld.*

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally.					Remarks.
	Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	
—	..	..	Cc	..	Wk	
O. thakil Salter .	..	..	..	..	..	Cc, Niti Pass.
O. moneta Eichw. .	Ag	..	..	..	..	
Leptæna Humboldti de Vern.	Ag	..	..	..	..	
Orthis polygramma Sow. var. *pentlandica* Dav.	..	..	Wk	..	..	
—	..	..	..	..	..	
Orthisina pyron Eichw.	L. Lo	..	..	..	..	
—	L. Lo	..	..	..	..	Ord., Lunschan, China.
—	Ag	..	Cc	..	..	
C. parvifrons var. *Murchisoni* Salter.	..	..	Ag	..	..	
C. nivalis Salter .	..	..	..	..	..	Cc, Niti Pass.
—	Ag	..	..	..	..	

TABLE 3.

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
CYSTIDEA.	
Echinoencrinus *cf.* angulosus Pander	Ord., Russia . . . . .
BRYOZOA.	
Diplotrypa (Mesotrypa?) palinensis Reed . .	Ord., N. Europe, America . .
BRACHIOPODA.	
Plectambonites repanda Salter	Ord.-Sil., Cosmopolitan . .
*Leptæna (?) ledetensis Reed	Ord.-Carb., Cosmopolitan . .
ARTHROPODA.	
Remopleurides sp.	Ord., Europe, N. America . .
Encrinurus (?) sp.	Ord.-Sil., Cosmopolitan . .
Pliomera ingsangensis Reed	Ord., Europe, N. America . .
Sphærocoryphe sp.	Ord., N. Europe . . .

Upper Naungkangyi Fauna.

Nearest Allies.	Horizon and Distribution of Species or Nearest Ally.					Remarks.
	Baltic Provinces Russia.	Sweden.	Great Britain.	Bohemia.	N. America.	
—	Ag	..	..	..	..	
Mesotrypa discoidea Ulrich.	..	..	..	..	Cc	
Mesotrypa quebecensis Ami.	..	..	..	..	Cc	
Leptæna repanda Salter.	..	..	..	..	..	Cc, Niti Pass.
Pl. segmentum Ang. var. *cornuta* Dav.	..	..	Ly-Lw	..	..	
Pl. geometrica Kut.	Lo	..	..	..	..	
—	..	..	..	..	..	
R. Colbii Portl.	..	..	Cc	..	..	
—	..	..	..	..	..	
Pliomerops canadensis Billings.	..	..	..	..	Ag	
Pliomera Fischeri Eichw.	Ag	..	..	..	..	
Cheirurus mitis Salter.	..	..	..	..	..	Cc, Niti Pass.
S. Hubneri Schmidt	Lo	..	..	..	..	

In the foregoing table I have left out of account those genera and species that have been only provisionally determined by Mr. Cowper Reed, though it is obvious that the occurrence of such trilobites as *Asaphus*, *Lichas*, *Bronteopsis*, *Ampyx*, *Harpes*, and *Agnostus*, and of such characteristically lower Ordovician forms as *Phacops* (*Pterygometopus*) *Panderi* and *Asaphus* (*Ptychopgye*) *Lawrowi* confirm in the clearest manner possible the general conclusions already formulated regarding the age of the Naungkangyi formation, that it corresponds with the Ordovician, Llandeilo and Caradoc or Bala groups, of Europe.[1]

Local distribution of the fauna.

Before proceeding to a discussion of the affinities of the fauna, it may be well to offer some remarks on its local distribution, which presents some peculiar features. And here I must repeat my former statement that the conditions of the country are such that it is extremely difficult to connect any one of the isolated exposures of rock with another except on lithological grounds, or to ascertain whether the fossils collected at any given spot are on the same horizon or not as those found in lithologically similar beds at another locality. Even where a rich fauna occurs it is often impossible to be quite sure to what horizon it belongs, owing to the extraordinarily isolated and unique character of the exposures. Thus the rich Cystidean fauna of Sedaw, described by Dr. Bather, has only been found at that one spot in the Shan States, and the only stratigraphical reason for supposing that it belongs to an horizon low down in the series is the fact that it has not been observed in other places where a comparatively complete sequence of rocks can be seen; the presumption being that if it does exist elsewhere, it is overlapped by higher beds.

Local range of species.

For these reasons it is impossible to treat the fauna of the Naungkangyi beds otherwise than as a whole for the present, including in the discussion the fossils both from the upper and lower groups. For if we leave out of account the cystideans from Sedaw, we find that of 14 determinable species described from the upper Naungkangyi beds, no less than 10 are also found in the lower group. No doubt, when the fossils hitherto undescribed, from the upper group, are worked out, the discrepancy will appear much

[1] F. R. Cowper Reed, Pre-Carboniferous Life-Provinces, *Records, Geol. Surv. Ind.*, Vol. XL, Pt. 1, p. 22.

greater; and as so many of these undetermined fossils are trilobites, I am in great hopes that with their help, and with that of the brachiopoda, it may be possible in the future to work out the true palæontological sequence, when the country is more opened up. But at present the attempt to make more than the broadest divisions, as I have done on lithological and stratigraphical grounds alone, would be hopeless, so far as the Shan States themselves as a whole are concerned; and I can do no more than suggest, as Mr. Cowper Reed has already done, in what way this formation is related to the Ordovician rocks of other countries.

Bionomical conditions.

The difficulty of determining the horizon of each exposure with respect to the whole series is enhanced by the fact that it is seldom that the fauna of any one locality is strictly comparable with that of another, but appears to depend upon purely local conditions of environment, as in the case of the Cystidean beds of Sedaw. The brachiopods, for instance, are most commonly found in calcareous sandy beds, the cystideans and trilobites in argillaceous shales; and the latter are so homogeneous in character over large areas that the lithological appearance of the rock gives no clue to the horizon of any particular outcrop. The sandy texture of the brachiopod beds, and the fact that when the remains of trilobites do occur in them (and they are often numerous and of large size, indicating individuals at least 4 or 5 inches across), they generally consist of single thoracic segments or fragments of a carapace, leads me to suppose that these beds were laid down on the shallower portions of the sea floor, where strong currents prevailed. If this was the case they would naturally be of a lenticular form, and not continuous over large areas. The bands of limestone also, which occur here and there among the shaly beds, seem to have been accumulated under similar conditions. They are to a great extent composed of the ossicles of crinoids, and are in the main what may be called a consolidated crinoid sand. Judging from the profusion of these ossicles in the rock, and of fragments of crinoid stems in the 'purple band,' there must have been an exceedingly rich crinoid fauna in the Ordovician seas of this region, of which these ossicles are the only traces that remain.

Himalayan equivalents.

The nearest region to which we may look for representatives of this series of rocks, leaving out of account for the present the small patches which are

known to occur in south-western Yunnen, and which are evidently only an extension northwards of the Shan States beds, is that of the Himalaya, where in the central parts,—in Spiti, Bashahr, and Kumaon,—Ordovician beds have been found, and their fossils described; those from the Niti Pass in Kumaon by Salter[1] so far back as 1865, and the whole of the collections more recently by Mr. Cowper Reed,[2] who had already described the Burmese fauna of the same period. His researches therefore have placed him in a position enabling him to speak with the highest authority on the relations, if any, that exist between the faunas of these two regions. The conclusions arrived at by him are expressed in the following words :—

"In spite of the great majority of the species" (from Spiti, etc.) "being peculiar to the Himalayas, we are led to observe that they mostly show affinities with American rather than European forms. This is surprising, particularly when the character of the Burmese Ordovician fauna is remembered, since its relations were seen to be clearly European."[3] . . . "The striking American stamp which the whole succession of faunas from the different horizons" (of the Himalaya) "possesses, must indicate that the European elements were almost entirely excluded from the marine basin in which these beds were deposited."[4]

Relations with North Europe.

In contrast with the foregoing he says, speaking of certain genera in the Burmese collections :—

"All these are especially characteristic of the lower Ordovician beds of Northern Europe and particularly of the Russian Baltic Provinces."

And of others :—

"These all suggest the Cystidean or Echinosphærite Limestones of Scandinavia and Russia which occur near the base of the Ordovician formation."

"The trilobites, as far as their scanty evidence carries us, have affinities which likewise point to the northern faunas of Europe in the Lower Ordovician period."

Again, of the Brachiopoda, though they "belong to species with a wide horizontal distribution and long vertical range," he remarks :—

"*Clitambonites squamata* is a Russian species occurring in the Echinosphærite Limestone. *Porambonites intercedens* is likewise a north European form . . . The species *Orthis calligramma, O. flabellulum, O. testudinaria, O. elegantula, Rafinesquina imbrex, Plectambonites sericea* and *Pl. quinquecostata* range through

[1] Salter and Blanford, Palæontology of Niti, in the Northern Himalaya.
[2] Ordovician and Silurian Fossils from the Central Himalayas; *Pal. Ind.*, Ser. X, Vol. VII, Mem. No. 2.
[3] *Loc. cit.*, p. 164.
[4] *Ibid*, p. 165.

the Llandeilo and Bala beds of Northern Europe and, though they do not help us to fix more precisely the horizon of the beds in which they are found, yet indicate the same zoo-geographical affinities of the Burmese Ordovician fauna. The fragmentary cystidean remains from all the fossiliferous localities point the same way. The only anomalous form is *Aristocystis*, which is typically a Bohemian and South European genus."[1]

Affinities of fauna.

Summarising the results of Mr. Cowper Reed's researches, as contained in the two Memoirs contributed by him to the Palæontologia Indica, we find that he has described 124 species from the Ordovician rocks of the Central Himalayas, and 47 from those of Burma. Of the former 52 (42 per cent.) are allied with American species, while only 31 (25 per cent.) may be compared with European forms. Of the latter, on the other hand, 13 species (27·7 per cent.) have American, while no less than 30 (66 per cent.) have European affinities. Furthermore, it should be noted that while among the Himalayan species only one, *Plectambonites sericea*, is identical with an American form, and only two, *Pl. sericea* and *Orthis porcata* with European species,—even such a cosmopolitan form as *Orthis* (*Dalmanella*) *testudinaria* being represented by a variety;—the Burmese fauna exhibits a far closer connection with that of Europe, no less than 10 species being identical. Comparing in the same manner the Himalayan with the Burmese fauna, we find that of the 124 species of the former only 11 (9 per cent.) are allied forms, and that only three of the peculiar forms, *Rhinidictya plumula*, *Plectambonites repanda*, and *Pliomera ingsangensis*, appear to be identical, though of this little trilobite Mr. Cowper Reed says:—

"It must be remembered that this supposed link only rests on one imperfect pygidium from Niti.[2]"

The only other identical fossil is the ubiquitous *Plectambonites sericea*.

Composition of the fauna.

But it is when we consider the composition of the faunas that the most striking discrepancies between the Himalayan and the Burmese areas appear. One of the most marked characteristics of the Naungkangyi beds is the extraordinary abundance of the remains of Cystideans, not always well preserved, it is true, but so

[1] Lower Palæozoic fossils of the Northern Shan States, Burma: *Pal. Ind.*, New Series, Vol. II, Mem. No. 3, p. 85.

[2] *Op. cit.*, *Pal. Ind.* Ser. XV, Vol. VII, Mem. No. 2, p. 166.

universally distributed through the rocks that almost every fragment that one breaks open contains portions of the detached plates. They must have literally swarmed in the seas of that period. In Spiti and Kumaon, on the other hand, though the rocks have been thoroughly searched, not a single specimen of this class of organism has been discovered. The trilobites are almost equally conclusive. Of the Himalayan forms Mr. Cowper Reed observes :—

"The scarcity of trilobites is a remarkable fact; with the exception of one or two individuals, no examples of this group occur on any other horizon but No. 2 . . . . The small size of the trilobites is noticeable, none attaining such dimensions as are usual amongst Ordovician Cheiruridæ, Asaphidæ and Illænidæ.[1]"

It is true that he also calls attention, in his Burmese Memoir, to the "rarity of the trilobites" as one of the characteristics of the Burmese fauna,[2] but this remark was made before the discovery of the rich trilobite localities and the numerous genera found therein by Mr. Coggin Brown and myself during the last two season's work in the Shan States, and no longer holds good; while many of the specimens of the genera mentioned above, and of others collected by us, will compare favourably in point of size with those from the Ordovician beds of Great Britain or of the Baltic. Representatives of no less than fifteen genera are now known to occur, and when it is remembered that these were collected from no more than a few square feet of rock in each outcrop accidentally exposed, and at localities far distant from each other, it is quite certain that further search will reveal the existence of a much greater profusion and variety of these organisms. The abundance of the detached eyes of trilobites in the Hwe Mawng beds, already alluded to, points the same way. Of the bryozoa, although individual specimens are common enough in Burma, there does not appear to be anything like the same variety of species as is found in the Himalaya, and only one, *Rhinidictya plumula*, is common to both areas. Of corals 5 species are described from the Himalaya, but the paucity of these fossils in Burma is most marked. The mollusca,—lamellibranchs and gastropods,—of which Mr. Cowper Reed has described 27 species from the Himalaya, appear to be hardly represented at all in Burma: and it is only among the brachiopoda that any points of resemblance are found, while these lose much of their significance when we reflect that

[1] *Ibid*, p. 164.
[2] *Op. cit.*, Pal. Ind., N. S., Vol. II, Mem. No. 3, p. 84.

only those genera and species which have a world-wide distribution are common to the two areas.

Extension into Yunnan.

The existence of strata of Ordovician age in Yunnan was first brought to light by v. Loczy, who has described them in the account of the expedition of Graf Bela Szechenyi to China (1877-1880).[1] The locality is situated at Pu-pjao, on the eastern side of the Salween river, on the road from Teng-yueh to Ta-li-fu, and the beds consist of slaty shales of various colours. The only fossils found by v. Loczy were some cystidean plates referred doubtfully to *Hemicosmites*, similar to those which are so common in the Naungkangyi beds, and are supposed by Mr. Cowper Reed to belong to *Caryocrinus*,[2] and very imperfect remains of trilobites; but the locality has more recently been visited by Mr. Coggin Brown, who is convinced that the Pu-pjao beds are identical with the Naungkangyi formation of the Shan States, and has collected a rich fauna, consisting of brachiopods and trilobites, and above all of graptolites, including well preserved specimens of *Didymograptus*, which, it is to be hoped, will go far in enabling the true horizon of the beds to be established, when their affinities have been worked out. As will be seen below, this is the third distinct graptolite horizon that has hitherto been discovered in south-eastern Asia. In addition to confirming v. Loczy's observation, Mr. Coggin Brown has also obtained, from a locality further to the south, a fine series of Cystideans, resembling in their mode of preservation and other characters the peculiar forms of Sedaw in the Shan States. His collections are now in the hands of Mr. Cowper Reed, and it is anticipated that a description of them will soon be ready for publication.

Equivalents in Central and North Eastern China.

A wide interval separates these localities in Yunnan from the representatives of Ordovician strata described by v. Richthofen, Bailey Willis, and others[3] as occurring in Central and north-eastern China. The formation there constitutes the upper part of the

[1] Reise des Grafen Bela Szechenyi in Ostasien, Vol. I, p. 767; Vol. III, p. 21.

[2] *Op. cit., Pal. Ind.*, New Ser., Vol. II, Mem. No. 3, p. 33.

[3] v. Richthofen, China, Vol. II, pp. 226, 319: Bailey Willis, Research in China, Vol. I, Pt. I, pp. 43, 269; Vol. II, p. 42: T. Lorenz, *Op. cit., Zeitschr. d. Deutsch. Geol. Gesellsch.* Bd. LVII, p. 447. In Bd. LVIII, Lorenz gives, on pp. 116 to 119, a useful summary of our knowledge of the Palæozoic formations of China and the neighbouring regions, to the year 1905: F. Leprince-Ringuet, Etude Géologique sur le Nord de la Chine; *Annales des Mines*, Ser. 9, Vol. XIX, p. 347, a *résumé* of v. Richthofen's researches.

Sinian system, and consists of limestones, the Tsij-nan and Ki-sin-ling limestones, in which a number of Ordovician fossils have been found; and although none of the Burmese species, except the cosmopolitan *Orthis calligramma* and *O.* (*Dalmanella*) *testudinaria* are identical, yet the facies of the fauna seems to be distinctly similar, as the following list, compiled from those given by Bailey Willis,[1] will show :—

Cornulites sp.
Lingula (?) sp.
Orthis calligramma Dalman.
„ (*Plectorthis*) *Willisi* Weller.
„ (*Dalmanella*) *testudinaria* Dalman.
Strophomena sp.
Clitambonites chinensis Weller.[2]
„ (*Hemipronites*) *tenuistriata* Weller.
Triplœcia Poloi Martelli.[3]
Cyrtodonta (?) sp.
Vaginoceras sp.
Ampyx chinensis Weller.
„ cf. *costatus* Boeck.
Asaphus lævis Weller.
„ *asiaticus* Weller.
„ *chinensis* Weller.
„ cf. *expansus* Dalman.
Illænus (?) *bronteoides* Weller.
Megalopsis minor Weller.
Bathyurus sp.
Isotelus sp.
Proetus (?) sp.
Calymene (?) sp.
Pterygometopus (?) sp.

Porambonites intercedens Pander, a fossil which occurs at Lebyaungbyán and Sedaw in the Shan States, has also been recognised by Martelli,[4] from the lower Silurian (Ordovician) of Shan-si.

1 *Op. cit.*, Vol. I, Pt. I, p. 270.

2 Stuart Weller, Descriptions of New Species of Ordovician Fossils from China; *Proc. U. S. Nat. Mus.*, Vol. XXXII, p. 557.

3 A. Martelli, Fossili del Siluriano Inferiore dello Schensi (Cina); *Boll. Soc. Geol. Italiana*, Vol. XX, p. 295.

4 *Op. cit.*, p. 304.

The new material from the upper Naungkangyi beds, now in the hands of Mr. Cowper Reed (*see* list, p. 85), may possibly lead to the establishment of a more definite relation between the Ordovician of the Shan States and of China, when the collections are examined.[1]

Nyaungbaw Limestones.

Occurrence.

Along the cart road from Mandalay to Maymyo, after surmounting the outer scarp of the plateau above the village of Kyetnapá (**B** 5), some red limestones are found extending from about mile post 21 to within a mile of the rest house at Nyaungbaw, disappearing, however, beneath the Plateau Limestone before reaching that place. At the village they are brought up again by a fault, and extend along the road beyond Yemeyé to the top of the steep ascent below Pyinthá. On this ascent they are well exposed, forming a dip-slope extending along the hill side to the north as far as the railway, where it ascends the steep gradients between Zebingyi and Thondaung stations.

Fossils.

The first fossil discovered in these beds, indeed the first to be found on the Shan plateau, was the peculiar organism collected by Dr. Noetling between Yemeyé and Pyinthá (Loc. 71, **B** 5), and supposed by him to be a gigantic species of *Echinosphærites*, to which he gave the name of *E. Kingi*, in honour of the Director of the Geological Survey at that time.[2] Dr. Noetling subsequently separated off the rocks containing these fossils from the rest of the limestones of the Shan plateau under the name of the Pyinthá Limestone,[3] but since it has been found that his group includes rocks of different ages, it has been thought advisable to confer the name of Nyaungbaw Limestone, given to them in 1900,[4] on these beds.

[1] While this Memoir was passing through the press, I was informed by Mr. Hayden, Director of the Geological Survey, that he had discovered representatives of the Naungkangyi group at Taunggyi, the capital of the Southern Shan States. No determinable fossils were found; but Mr. Coggin Brown, who is well acquainted with the Naungkangyis of the Northern States, is convinced that the beds belong to this formation.

[2] Field Notes from the Shan Hills, *Records, Geol. Surv. Ind.*, Vol. XXIII, Pt. 2, p. 78.

[3] Coal-fields in the Northern Shan States; *Ibid*, Vol. XXIV, p. 104.

[4] General Report, *Geol. Surv. Ind.*, 1899-1900, p. 82.

Lithological characters.

The rocks of this formation consist for the most part of red or chocolate brown limestones passing into grey or bright blue, and sometimes purple limestones. Bands of red clay are interbedded with these, and the limestones themselves usually contain a large amount of argillaceous matter, in such cases presenting a peculiar lenticular structure, like that of the German 'Knollenkalk' or 'Netzkalk.' It also resembles that already described as characterising the more calcareous portions of the purple band at the top of the upper Naungkangyis (p. 92).

Camarocrinus.

The large fossil named *Echinosphærites Kingi* by Dr. Noetling has since been examined and fully described by Mr. Cowper Reed, whose account of it is published in the Palæontologia Indica (*Op. cit.*, p. 88, Pl. VIII, figs. 16, 16*a-c*), under the name of *Camarocrinus asiaticus*. (A photographic reproduction of the type-specimen is given in Plates 25 and 26). The genus has been studied by Prof. Schuchert,[1] who has described several species from the Helderberg Group of West Virginia, Indian Territory and Tennessee, U. S. A. In Bohemia a similar fossil, named *Lobolithus* by Barrande, is found, but at a lower horizon, namely, in the stages E 1 b and E 2, whereas the Helderberg Group corresponds to the Bohemian stage F. The organism was conjectured by Hall to be a chambered bulb attached to the root of a crinoid, to act as a kind of float or anchor to the body and arms. Prof. Waagen and Dr. Jahn of Vienna, who have described the specimens collected by Barrande, agree with this view, but Dr. Jahn also supposes that they might represent 'brood receptacles' (*Brutsbehälter*), and that some of them were a modification of the root of *Scyphocrinus*, with which they are often found in association in Bohemia. Prof. Schuchert, however, does not accept the views of Dr. Jahn on these latter points, remarking that *Scyphocrinus* is unknown in America, and that in the beds in which *Camarocrinus* occurs in large numbers, the remains of other crinoids are very rare. He is also convinced, from inspection of the actual occurrence of *Lobolithus* with *Scyphocrinus* in Bohemia, that the connection between the two is fortuitous (*Op. cit.*, p. 262). He suggests, however, that since *Camarocrinus* was evidently not a complete animal, nor the theca of either a cystid or crinoid, being

1 Siluric and Devonic Cystidea; *Smithsonian Miscell. Coll.*, Vol. XLVII, Pt. 2, pp. 53–272.

devoid of either ambulacra, mouth, or anus, and was apparently intended to be a float of some kind, it drifted away on the death of the individual to which it belonged, shedding the crown and stalk, and finally, becoming filled with water, sank to the sea bottom at a distance from its original habitation (*Op. citi*, p. 267). This supposition would explain why it is that crinoid calices and other fragments are so rarely found associated with *Camarocrinus*.

Association with *Scyphocrinus* in Burma.

It is worthy of remark in this connection that *Camarocrinus asiaticus* is associated, in the Nyaungbaw Limestone, with large numbers of the remains of a crinoid, which Mr. Reed has recognised as probably *Scyphocrinus*, the genus that is commonly found together with *Lobolithus* in Bohemia. At the 21st mile on the cart road, about 2 miles west of Nyaungbaw (Loc. 70, **B** 5), Mr. Datta discovered whole slabs of rock, a pink limestone, covered with the interlaced brachial ossicles and stem joints of this crinoid, and I have since found imperfect specimens of *Camarocrinus* in the same bed. On the other side of Nyaungbaw also, near Yemeyé (Loc. 71), at the foot of the zig-zags leading up to Pyintha, where the best preserved and most numerous specimens of *Camarocrinus* occur, an imperfect calyx was obtained, closely allied, according to Mr. Cowper Reed, to *Sc. excavatus*, from Étage E 1—E 2 of Bohemia. The association of *Camarocrinus* with *Scyphocrinus*, both in Bohemia and in Burma, is certainly suggestive of a more intimate connection between the two genera than Prof. Schuchert is willing to admit, but it must be confessed that no specimens have yet been discovered that point to anything more than a merely accidental grouping together of the remains in the same beds.

Horizon of Nyaungbaw Limestone.

In a short review of Mr. Cowper Reed's work, published in the American Journal of Science (4th series, Vol. XXV, p. 262), Prof. Schuchert takes exception to the position assigned by me to the Nyaungbaw beds at the top of the Ordovician system, and remarks that "the palæontological evidence" as then presented "clearly places this formation in close association with the Zebingyi beds," at the base of the Plateau Limestone. But when it is considered that *Camarocrinus* belongs to very different horizons in Bohemia and America respectively,—no less than four formations intervening

in the latter country between the Rochester Shale, the equivalent of the stage in which it occurs in Bohemia, and the Helderberg Group,—it appears to me that it would be unsafe to argue too closely from its presence here regarding the relative age of the deposit. Moreover, the stratigraphical evidence indicates that there must have been a considerable interval between the period of deposition of the Nyaungbaw Limestone and that of the Zebingyi beds; for not only is a whole formation, the Nám-hsim sandstone, of Wenlock age (which on the Nám-Tu attains a thickness of at least 2,000 feet), almost entirely absent in the western sections, where the Nyaungbaw and the Zebingyi beds are in contact; but I have also convinced myself, having been over the ground several times, that there is a decided unconformity between these two formations. This may be observed in the railway cuttings about a mile below Zebingyi station, and in a small cutting about a quarter of a mile east of Thondaung station, where the Zebingyi beds are actually seen resting upon an eroded surface of the Nyaungbaw Limestone, one of the very few instances I know of where the actual contact of two formations is visible (Plate 9, *see also* fig. 5, p. 169).

Distribution.

The Nyaungbaw Limestones appear to cover a very restricted area. Some patches of them occur among the hills north of Maymyo (Loc. 72, **C** 4), where specimens of *Camarocrinus asiaticus* were found by Mr. E. A. Gabbett, Executive Engineer in the Public Works Department, in quarrying the stone for the Municipal Water-works Reservoir. Hence they extend at intervals to the north, forming a line of conspicuous ridges near Palin, about 6 miles north of Maymyo, where a few fossils were found in them, including *Diplotrypa palinensis* Reed; *Lingula* cf. *quadrata* Eichwald; *Plectambonites repanda* Salter; and *Orthis irravadica* Reed. Of these the first and last are new species; the *Diplotrypa* differs from that of Sedaw in possessing no acanthopores and in the irregularity of the diaphragms in the mesopores, and in the former respect resembles *Mesotrypa quebecensis* Ami and *M. discoidea* Ulrich. The *Orthis* is a common Naungkangyi form. *Lingula quadrata* occurs in the Ordovician beds of Russia and the Craighead limestone of Girvan, and *Plectambonites repanda* in the Ordovician of Niti. So far as these fossils go, therefore, the Nyaungbaw Limestone would seem to belong to a lower horizon than the beds with *Lobolithus* in Bohemia, which correspond to the Wenlock and Ludlow of England, or than

the *Camarocrinus* beds of America, corresponding to Étage F in Bohemia or the Lower Devonian, and to be more closely connected with the underlying Naungkangyi than with the overlying Zebingyi beds.[1]

Possible representatives in the Eastern Ranges.

The Nyaungbaw Limestones have not been found further east than this, unless, as is possibly the case, they are represented by the purple band at the top of the Naungkangyis in the Nám-Tu valley, and by the upper part of the Hwe Mawng beds in the eastern ranges. Certainly the limestones, which form a part of the purple zone, resemble them very closely; and in the far east, on the Nám-hen between Pinghsai and Kehsi Mansam, and again on the Nám-Pung, a tributary of the Nám-Pang, in South Hsenwi, there are some limestones, quite at the top of the Hwe Mawng beds, which, as far as lithological appearance goes, are identical. But in the absence of any direct palæontological evidence of identity,—for neither *Camarocrinus*, nor indeed any recognisable fossil, except crinoid fragments, have been found in these eastern beds, —their correlation with the Nyaungbaw limestones of the west must remain doubtful.

[1] Prof. Schuchert, to whom I submitted the manuscript of this portion of my Memoir, has very kindly sent me some notes on the position and relationships of *Camarocrinus*. He was at first sceptical as to the stratigraphical horizon attributed by me to these beds, as he thought that the evidence of unconformity between the Nyaungbaw and Zebingyi beds was not convincing: but he now accepts the statement that the discovery of *C. asiaticus* in the limestones to the north of Maymyo, on the same strike as those with *Diplotrypa palinensis*, *Lingula* cf. *quadrata*, and *Orthis irravadica*, which was not known to him at the time that his criticism of Mr. Cowper Reed's Memoir was written, indicates the Ordovician age of the Nyaungbaw Limestone. He still thinks, however, that until more direct evidence of the association of *Camarocrinus* with *Scyphocrinus* is forthcoming, it cannot be inferred that this was the only crinoid that was furnished with these floats. One objection to the supposition that these bodies served as the floats of crinoids does not appear to have been noticed, *viz.*, the presence of pores at the margin of each plate forming the test. These are not shown

in Mr. Cowper Reed's figures, but are clearly visible in the full-size photographic views of the fossil reproduced in this Memoir (Plates 25 and 26). These pores seem to denote that the interior of the bulb was filled with living tissue, not with air alone; otherwise it is difficult to see what function they could have served; and indeed they would seem to be the last characteristic one would expect to find in an organism intended to be impervious to water; for even if they were sealed by a membrane of some kind, the use of the bulb as a float would have been destroyed by the least abrasion.

From a sketch by the author.

Fig. 4. The Kyaukmò Falls.

CHAPTER VII.

SILURIAN SYSTEM.

Nomenclature.

The local names given to the formations in the Northern Shan States belonging to the Silurian system are the following, in descending order :—

UPPER SILURIAN .	Zebingyi beds. Upper Namhsim, or Kônghsa Marls. Lower Namhsim (Sandstones).
LLANDOVERY .	Panghsa-pyé Graptolite band.

As in the case of the Ordovician strata, these formations are not always present, one of them, the Zebingyi beds, being of extremely local development. It will be seen in the sequel, also, that there is some doubt as to whether this formation should not be included with the Devonian Plateau Limestone immediately overlying it.

Llandovery Group.

(Panghsa-pye Graptolite Band).

Occurrence and characters.

Immediately above the purple shales at the top of the Upper Naungkangyi beds exposed in the valley of the Nám-Tu, a band of white shales is found, containing graptolites in large numbers. This band has not been detected anywhere to the west of Panghsa-pyé, an easily accessible village on the Nám-hsan road about eight miles north-west of Hsipaw, though the purple shales have been traced as far as the Gokteik gorge. It is very liable to erosion, however, on account of its soft character, and its outcrop is apt to be concealed by rainwash ; and it is therefore possible that this band may yet be found to occur in that direction. Unfortunately the discovery of the graptolites was not made, by Mr. Coggin Brown and myself, until after the country to the west had been traversed, and it has been found impossible to revisit it ; but the horizon at which the graptolite band should occur is so well marked by the purple shales beneath that there should be no difficulty in determining whether it is present or not.

List of fossils.

The chief interest of these rocks lies in the fact that they contain the only fauna of undoubted Llandovery age that has yet been found in the East. The fossils collected from them, in the area mentioned above, have been provisionally determined as—

Hydrozoa—

Diplograptus (*Orthograptus*) *vesiculosus* Nicholson.
,, (*Mesograptus*) *modestus* Lapworth.
,, (*Glyptograptus*) cf. *persculptus* Salter.
Climacograptus medius Törnquist.
,, *Törnquisti* Elles and Wood.
,, *rectangularis* McCoy.
Monograptus tenuis Portlock.
,, *gregarius* Lapworth.
,, *cyphus* var. *minor* Lapworth.
,, *concinnus* Lapworth.
Rastrites peregrinus, Barrande.

Anthozoa—

Palæocyclus (?) sp.

Brachiopoda—

Orthis (*Dalmanella*) sp. (aff. *elegantula* Dalman).
,, aff. *hirnantensis* McCoy.
Scenidium aff. *Lewisi* Davidson.
Orthothetes aff. *pecten* Sowerby.
Strophomena sp. nov.
Rhynchonelloid (genus indet.).
Plectambonites (?) sp. nov.

Mollusca—

Holopea sp.

Arthropoda—

Phacops (*Dalmanites*) sp. nov. (aff. *imbricatus* Angelin).
Acidaspis sp. nov. (aff. *quinquespinosa* Salter).
Beyrichia sp.
Turrilepas sp.

Section of Panghsa-pyé.

A fairly clear section of these beds is exposed at Panghsa-pyé (Loc. 65, **F** 2), at the base of a precipitous sandstone scarp, formed of the higher Silurian rocks, about a quarter of a mile south-east of the village. The strata here are seen to be conformable to each

other, the whole dipping to the south-east at about 30 degrees. The band containing the graptolites consists entirely of fine white shales, and is of no great thickness, probably not more than 50 feet, throughout which the graptolites seem to be fairly evenly distributed. No other fossils were found actually associated with the graptolites, but just below the horizon in which they are most numerous, and a few feet only above the top of the purple beds a stratum of yellow sandy shale occurs crowded with the remains of trilobites of more than one species. The abundance of the remains of individuals in this stratum, although it is not more than six inches thick, is astonishing; and though they are much broken up, the minutest details of their structure are preserved. Immediately beneath this is a layer of well preserved specimens of brachiopods, probably including several species, but neither these nor the trilobites have yet been accurately determined.

Graptolites.

The fossils from this locality have not yet been described in detail, but the graptolites have been examined by Miss G. L. Elles, and are pronounced by her to be of undoubted Llandovery age; in fact, one of them, *Diplograptus* (*Orthograptus*) *vesiculosus* Nich., is one of the zone fossils of the Lower Llandovery, characteristic of the middle division of the Lower Birkill shales of Southern Scotland. The other graptolites are *Diplograptus* (*Mesograptus*) *modestus* Lapw., *Climacograptus medius* Törnq., *C. rectangularis* McCoy, and *Monograptus tenuis* Portl., all of which occur in the zone of *O. vesiculosus* in Britain.

Trilobites.

There are two trilobites in the layer at the base of the graptolite band, a new species of *Phacops*, allied to *Ph. imbricatus* Ang., and an *Acidaspis*, which is interesting as the only species of this genus that has yet been found in these hills. It is a small trilobite, and the head shields alone have been found, but it is fairly common. The brachiopods, etc., mentioned in the list given above were also collected at this locality.

Nám-Tu valley.

In the valley of the Nám-Tu, north of Panghsa-pyé, the graptolite band is found in several places, both at the base of the scarp to the east of the river, and on the spurs on the west side at the base of the outliers of Upper Silurian sandstone which occur above Tapôk and Ta-pangtawng ferries. On the east bank graptolites were found on the path to Lilu ferry, about a mile below the crossing (Loc. 59,

F 1), but in a very soft, decomposed condition. Better preserved specimens, in large numbers, may be collected at the village of Ngai-tao (Loc. 64, **F** 1), on the spur above Ta-pangtawng. The most important form is *Monograptus gregarius* Lapw., the zone fossil of the upper division of the Lower Birkill shales. With this are associated *Rastrites peregrinus* Barr. and *Climacograptus Törnquisti* E. and W., which are, according to Miss Elles, also characteristic of the zone of *M. gregarius*. *Diplograptus* (*Mesograptus*) *modestus* and *Monograptus cyphus* var. *minor* Lapw. are also to be found here. We have thus two well-defined horizons of the Lower Llandovery represented in the Nám-Tu valley; but it remains to be seen whether they are actually situated on two distinct stratigraphical planes in this area; and this can only be done by careful search throughout the whole thickness of the beds exposed in each section.

Nám-pang-yun.

Further north again, beyond the limits of the map, graptolites were found by Dr. J. M. Maclaren in a similar position on the Nám-pang-yun, about a mile above its conflux with the Nám-Tu, on the way to the Bawdwin silver mines. Here they occur in a black, carbonaceous sandy shale, and are very ill-preserved, in fact only just recognisable as graptolites.

Occurrence in Eastern Ranges.

Loi-len range.

The graptolite band is met with again among the hill ranges east of the plateau, resting upon the purple Hwe-Mawng beds. In the Loi-len range, east of Lashio, it was found on the south slope of the ridge about two and-a-half miles E.N.E. of the village of Pangmé (Loc. 66, **H** 1). At this locality the graptolites occur not only at the top of the purple beds, but also in some white shales interbedded with the latter. A species of *Climacograptus* is the most common form that was found here, but time did not allow of a thorough search being made, or of a second visit to the locality. Further to the south the graptolite shales have not been detected in any of the sections exposed along the flanks of Loi Ling, or among the hills east of Möng-Yai, but a small outcrop was found at

Mong-keng dome.

the top of the Hwe-Mawng beds forming the dome-shaped mass of hills between Loi Ling and Mong-keng, close to the small village of Nám-hsim (J 2). They reappear, however, in the same position on the eastern flanks of the Loi Pan range in Kehsi Mansam, between Möng-

Lá and Ping-hsai, and may be collected on the path from this place to Mán-Shio, just above the village of Pangsam (Loc. 67, **H** 4).

East side of Loi Pan.

About a mile south by east of Ping-hsai, in the gorge of the southern branch of the Nám-Hen (Loc. 68, **H** 5), graptolites occur in large numbers, but under a different aspect, for the beds in which they are found here are highly carbonaceous, sandy shales, similar to those on the Nám-pang-yun, with lenticular bands of coaly stuff; they occupy the same position with regard to the purple beds, however, as at other localities, and according to Miss Elles, the fossils are a characteristic assemblage from the upper part of the zone of *Orthograptus vesiculosus*, that is to say, are almost of the same age as those of Panghsa-pyé. They include, besides *O. vesiculosus*, *Monograptus tenuis* Portl., *M. cyphus* var. Lapw., *M. concinnus* Lapw., *Diplograptus* (*Mesograptus*) *modestus* Lapw., *D.* (*Glyptograptus*) cf. *persculptus* Salter, *Climacograptus rectangularis* McCoy, and *Cl. medius* Törnq. No other fossils were found associated with these graptolites.

Nám-Há valley.

One other graptolite locality may be mentioned here, for though it undoubtedly belongs to a somewhat higher horizon, its stratigraphical position, so far as can be seen, corresponds to that of the Panghsa-pyé band. It is exposed in a cutting on the path from Mong-Há to Nawá, in the valley of the Nám-Há among the hills east of Möng-Yai, close to the village of Kanlun (Loc. 69, **I** 3). Two species of graptolite were found here, *Monograptus priodon*, the well-known Wenlock form, and a species of *Cyrtograptus*, which is also a distinctively upper Silurian genus. Only one exposure of these beds was met with, and their exact horizon cannot yet be determined.

Lower Namhsim Stage.

Omission from original reports.

When the survey of the Shan plateau was taken up in the year 1899, the first portion to be traversed was that immediately adjacent to the railway, then in course of construction, and the cart road from Mandalay to Lashio, and it so happened that the formation now to be described is not passed through by either of these works, while time did not admit of excursions being made to places

on either side of the route taken: neither Mr. Datta, therefore, or the present writer, who carried out that traverse, became aware of the existence of any rocks between the Naungkangyi group and what were then named by us the Zebingyi beds, at the base of the Plateau Limestone or 'Maymyo beds' of our first reports. No mention of this formation, consequently, appears in our respective accounts of the geology, published in the General Report of the Geological Survey of India, 1899-1900 (pp. 74, 122). It was not until the next field season that I discovered a patch of felspathic sandstones, with coarse conglomerates at their base, on the crest of the Memauk spur overlooking the village of Aunglôk (Loc. 47, **B** 4), at the extreme edge of the western scarp, and found in the sandstones specimens of fossils, which I recognised as belonging to the well-known Silurian genus *Orthonota*, with fragments of trilobites. Later on in the same season I found, on the south side of the gorge of the Námhsim at Hkyawngtwang (**E** 2), about 13 miles above its conflux with the Nám-Tu, a series of sandstones, reaching a thickness of over 1,200 feet, intervening between the purple beds at the top of the Naungkangyis exposed in the bed of the river and the base of the Plateau Limestone crowning the scarp. To these beds I gave the name of Námhsim Sandstones, and afterwards found that in the Nám-Tu valley they attain a thickness of at least 2,000 feet, and extend for a long distance along the banks of that river.

Two divisions recognised.

As in the case of the Naungkangyi group, the fossils that were collected from the whole of the Námhsim formation were sent to Mr. Cowper Reed before the stratigraphical features of the beds had been studied in detail, and it was not until his Memoir had been published that it was found that at least two fairly well-marked divisions could be detected; one consisting of the Námhsim Sandstones, as understood at first, now described as the lower division, and the other of a much thinner band of marly beds with hard limestones, which appeared to have a close connection with the overlying Zebingyi beds, and was described along with the latter in my report on the first traverse (Gen. Rep. 1899-1900, pp. 79, 88). Since that report was written, however, it has been found that the marly beds have a very much wider distribution than the Zebingyi graptolite-bearing beds, and that their association with the Námhsim Sandstones is equally close. Moreover, some of the fossils from this band have been described

by Mr. Cowper Reed as coming from the Námhsim formation, and it will therefore be convenient to include it as an upper division of that group.

List of fossils.

The fossils from the lower division of the Námhsim formation, or Námhsim Sandstones, are the following, as determined by Mr. Cowper Reed (Pal. Indica, N. S., Vol. II, Mem. No. 3, p. 90, seq.). New species are printed in heavier type.

Brachiopoda—
Mimulus **aunglokensis** Reed.
Orthis sp.
Mollusca—
Orthonota (?) **spectabilis** Reed.
„ sp.
Pycnomphalus sp.
Orthoceras aff. *tenuiannulatum* McCoy.
Arthropoda—
Illænus aff. *æmulus* Salter.
Proetus sp. *α*.
„ sp. *β*.
Encrinurus **kongbsaensis** Reed.
Calymene Blumenbachi Brongniart.
Cheirurus cf. *bimucronatus* Murchison.
„ (?) **inexpectans** Reed.
Phacops (*Dalmanites*) *longicaudatus* Murch. var. nov. **orientalis** Reed.

Lithological characters.

This list is not a long one, but although several new localities for fossils have been discovered among these rocks since it was compiled, the number of species has not been increased; it is sufficient, however, to enable the age of the formation to be determined. As the whole of the beds are of a sandy nature, sometimes very coarse in texture, and elsewhere fine grained and compact, hard and splintery, it is not to be expected that they would be very prolific in organic remains. Still, in a few places, where softer fine-grained layers occur, the number of individual specimens that may be collected is considerable. As a rule, the fossils are found only in loose blocks, either weathered out on the surface of the hill slopes or in the beds of streams; and as there are no quarries, and such cliff

sections as occur are generally inaccessible on account of the dense vegetation, the exact horizon from which the fossils have been derived can very seldom be ascertained.

Outlier on Memauk spur.

Starting from the western edge of the plateau, the first point at which these beds are met with is the locality already mentioned, on the crest of the Memauk spur, overlooking the valley of the Chaung-Magyi at Aunglôk (Loc. 47, **B** 4). The occurrence here is completely isolated, the sandstones occupying a very small area surrounded by older rocks, on which they rest unconformably (Section II, Plate 23). At the eastern end of the exposure the rocks beneath them are the upper Naungkangyi variegated shales, dipping apparently at high angles, but at the western end these are absent, and the Námhsims rest directly upon the much older rocks of the Chaung-Magyi series, also highly inclined. At the extreme western end of the ridge the basement beds of the Námhsims are seen, consisting of very coarse conglomerates, in which boulders and pebbles of the Chaung-Magyi quartzites predominate, mingled with a few from the crystalline series of Mogôk, which is *in situ* on the further side of the Chaung-Magyi valley. The conglomerates pass upwards into a series of rather coarse-grained, blue and purple, felspathic grits and sandstones, in the more fine-grained layers of which the fossils occur. The horizon of these, therefore, is not far above the base of the series. They comprise *Mimulus aunglokensis* Reed; *Orthis* sp.; *Orthonota*(?) *spectabilis* Reed; two undetermined species of *Proetus*; and *Cheirurus* (?) *inexpectans* Reed. Of these *Mimulus aunglokensis* occurs in considerable numbers; the genus is confined to the Bohemian area, except for one species, *M. waldronensis* Miller and Dyer, from the Niagara group of N. America. In Bohemia it occurs in Étage E 2, corresponding to the Wenlock formation in England, and the Bohemian *M. contrarius* Barr. bears a considerable resemblance to the Burmese form. The *Orthis* is in too poor a state of preservation for specific determination. The genus *Orthonota* is characteristically Silurian, but species have been described both from Bala and Devonian rocks. In America *Orthonota s. s.* is confined, according to Hall, to the Hamilton and Chemung groups, or middle and upper Devonian, but the Burmese species bears some resemblance to *Sanguinolites* (*Orthonota*) *decipiens* McCoy, from the upper Ludlow. Ill-preserved

Conglomerates at base.

Fossils.

casts of *Orthonota* are not uncommon at other localities in these sandstones, though they are so imperfect that it is hopeless to attempt to make out their specific characters. Of the two species of *Proetus*, both of which are very imperfect, the one designated *α* by Mr. Cowper Reed bears some resemblance to the Wenlock species *Pr. Fletcheri* Salter, while sp. *β* differs from this in having a more oval, pointed, and deeply lobed glabella. The genus has a wide range, from Ordovician to Devonian. Regarding *Cheirurus inexpectans* Mr. Reed says :—

"There is only one specimen of this peculiar little trilobite. Its generic position seems to be in *Cheirurus*. The very forward position of the eyes and of the first lateral furrows of the glabella, the lobation of the glabella, and general course of the facial sutures, suggest an alliance with *Ch. vinculum* Barr., but the latter is an Ordovician species." (*Op. cit.*, p. 137.)

Relations with Plateau Limestone.

It is somewhat remarkable that, although this patch of sandstone occurs close to the line of cliffs bordering the western edge of the plateau, along the top of which the Plateau Limestones are found extending in an unbroken line from north to south, no trace of it has been detected at the base of these limestones, which, throughout the whole distance, appear to rest directly upon the upper Naungkangyi beds. The sandstones must either have been deposited over a very limited area at this locality, or they must have been subjected to denudation before the limestones were formed.

Northern edge of Plateau.

The Námhsim Sandstones next appear along the northern edge of the plateau, between Kalagwé and the valley of the Nám-panhsé at Pa-môn. They are not, however, seen actually below the limestone of the plateau, but occur as outliers on the spurs of the hills, formed of Chaung-Magyi rocks, immediately to the north. It is possible that their non-appearance beneath the limestones here is due to faulting along the base of the hills, but it may also be caused by an overlap of the limestones. The only fossils obtained from this area, on the spur north of Námhsu-hká and south-east of Nan-yôk (**C** 2), were poorly preserved casts of a gastropod, which Mr. Cowper Reed considers, with some hesitation, to be a *Pycnomphalus*, comparable with *Trochus helicites* Sowerby, from the upper Ludlow and lower

Devonian of England, and with *Pyc. acutus* Lindstr., from Gotland (Ludlow formation). Casts of this gastropod are not uncommon elsewhere in the Námhsim Sandstones.

Nám-Tang valley.

At the Gokteik gorge the lower Námhsims do not appear to be represented at all, the poor exposure of soft brown sandstones, between the 88th and 89th miles on the cart road near Pomaw (**D** 3), which will be again referred to, belonging to the upper part of the formation; but further to the north, in the angle formed by the Nám-Tang north of Makhinsuk, they occupy a considerable area. Fossils were found in two localities in this area, of which the one named Manna 2 (Loc. 49, **D** 3) in Mr. Cowper Reed's Memoir (*Op. cit.*, p. 148) is on the lower Námhsims. *Pycnomphalus* sp. and an *Orthoceras*, allied to *O. tenuiannulatum* McCoy, from the Ludlow formation, are the only two species described. These fossils, as well as the *Pycnomphalus* from Námhsuhká, probably come from a fairly high horizon in the formation.

Fossils.

Section at Námsaw.

Higher up the Nám-Tang, on the right bank opposite Námsaw, the lower Námhsims are well developed, forming precipitous cliffs several hundred feet high overhanging the river, and running across the boundary of the upper Naungkangyi shales on to the highly disturbed rocks of the Chaung-Magyi series forming the lofty hills to the north and west, across which the cart road to Möng-Lông is carried. From Námsaw eastwards the sandstones gradually thicken out, and occupy a widely increasing area as far as the valley of the Nám-Tu, north of Hsipaw. They form the greater part of the mass of low hills seen in the foreground to the north of the railway between Pyaunggaung and Kyaukmé stations. Hence they extend up to and beyond Kiohsio (N. (**E** 2), to the north of which village they form a line of picturesque pine-clad cliffs, backed by the higher peaks of Ponglông in the Tawngpeng State. Here again they overlap the Naungkangyi beds, running across the boundary of the latter and capping, as outliers, the higher peaks in the neighbourhood. Their limits can be distinguished at once by the lines of cliffs that they form, overhanging the more gentle slopes of the schistose and slaty beds of the Chaung-Magyi series beneath them. This overlap is continued across the valley of the

North-easterly extension.

Outer boundary.

Námhsim, passing to the west of Kunkaw, and then northwards through Hunang and Kunhawt to and beyond Tawngmá (**F 1**). The boundary with the older rocks is deeply eroded and exceedingly tortuous, on account of the enormously deep, narrow ravines by which the whole of the State of Tawngpeng is intersected. Outliers of the sandstones, occupying the higher points of the hills, are numerous. The boundary is sometimes marked by beds of coarse conglomerate, consisting of water-worn pebbles and boulders of the Chaung-Magyi quartzites. Where these are absent the lower beds of the sandstone series are usually coarse-grained, and for some distance up from the base they are strongly felspathic, and generally of purplish or bluish grey colours, like the *Orthonota* beds on the Memauk spur described above. These gradually become less felspathic, passing into fine-grained, brown sandstones, with layers of a hard, white, very fine-grained quartzose sandstone. Fossils are somewhat rare, but occasionally the cast of an *Orthonota* or a fragment of a trilobite may be found.

Conglomerates and grits at base.

The inner boundary of the sandstone series is always easily discernible, on account of the contrast with the overlying Plateau Limestone, beneath which the sandstones usually form well marked and precipitous scarps. It is to be noted, however, that where the existing drainage has cut down to the base of the sandstones, and has exposed their plane of contact with the underlying Naungkangyi group, the basement beds are very different from those just described, along the outer boundary. There are no conglomerates, or even traces of a coarsening of the sandstones as the base is approached, and wherever a fairly clear section is obtainable, as on the Panghsa-pyé saddle, on both sides of the Nám-non ravine, and in the gorge of the Nám-Tu, the fine-grained sandstones are seen to rest with apparent conformity upon the graptolite beds beneath them. The absence of the latter, however, in some places where they ought to occur, as in the deep gorge of the Námhsim at Hkyawngtawng, seems to show that there may have been some erosion of the underlying beds before the sandstones were deposited, and that consequently there may be a slight amount of unconformity. In any case it is evident that the sandstones were deposited in a sea shallowing rapidly towards the north, and that at this time the older rocks of the Chaung-Magyi series formed a land area in that direction.

Inner boundary.

Lilu overthrust (Section IV, Plate 23, and Plate 22).

A traverse across the valley of the Nám-Tu from east to west, in the neighbourhood of Lilu, brings to light one of the most interesting structural features of the geology of this region, which has been alluded to before (p. 55), but a full account of which I have kept back until I had reached the description of the Námhsim Sandstones, since these rocks have played a conspicuous part in elucidating the structure referred to. Descending from Námmo village (**F** 1), at the edge of the fairly level plateau extending northwards from Hkawnghsá, on the east side of the gorge, we first climb down a precipitous scarp formed of the Námhsim Sandstones, which here attain a thickness of about 2,000 feet. Near the base of the scarp we come upon the graptolite band of Panghsa-pyé,—which is not well exposed, but may be found on the path leading along the edge of the river about a mile south of Lilu ferry (Loc. 59),—and beneath this the purple band, which has been traced at intervals along the river bank as far north as Tapangtawng ferry. All these beds dip to the east at an angle of about 30 degrees. In the bed of the river, at and just above Lilu, some strong bands of limestone are exposed, and immediately beneath these the variegated shales of the upper Naungkangyis, also dipping in the same direction, and forming a dip slope on the western bank extending up the spurs on either side of the deep ravine which joins the gorge of the Nám-Tu at this point. If now we ascend the spur on the southern side of the ravine, instead of finding a regularly descending section through the lower Naungkangyis to the Chaung-Magyi rocks of the hills beyond, we pass directly, after surmounting the first steep rise, on to sandstones exactly similar to those forming the scarp on the eastern bank, and dipping steeply to the east at angles of 60° or more, while these sandstones are found to contain specimens of *Orthonota*, etc., and therefore belong to the Námhsim formation. Continuing along the spur to the peak, 6,019 feet, immediately south of Tawngmá, the dips again flatten out, and the sandstones, here very coarse and felspathic, are seen resting directly upon the Chaung-Magyi rocks, on the western slopes of the Tawngmá peak, the Naungkangyis being entirely absent. At first it seemed as if the structure might be explained by simple overlap of the Naungkangyis by the sandstones, but the high dips at the crest of the spur could not be accounted for in this way; moreover, there is no question but that the sandstones do actually dip beneath the Naungkangyi beds. The true explanation is, I think, revealed

if we follow up the section in the Lilu ravine, instead of ascending the spur. Here the variegated Naungkangyi shales are succeeded normally, about a mile above the village, by the *Orthis* and *Rafinesquina* beds of the lower Naungkangyis, with a higher easterly dip than at Lilu itself. But a little further on, at the entrance to a narrow gorge just above the small village of Napeng, we come upon the sandstones, which were seen on the spur above, dipping at an angle of 60° beneath the Naungkangyis. It seems then that what we have here is in the first place an overlap by the Námhsim Sandstones of the Naungkangyis, subsequently dislocated by an overthrust fault or fold parallel to the river, the beds having given way along the comparatively soft layers of the Naungkangyi shales, under the stress of an impulse acting from the east, and been driven up over the hard sandstone strata. The cause of such a dislocation having taken place along this particular line is perhaps to be found in the existence, only a short distance to the west, of the unyielding mass of the older Chaung-Magyi rocks, forming the old land area of Tawngpeng. The fault plane runs almost due north and south, and has been traced from the Panghsa-pyé saddle, where it passes a short distance to the west of the village, into the Bawdwin area to the north, beyond the limits of the map, where the disturbance of the rocks caused by it has, no doubt, facilitated the impregnation of the strata with the mineral ores for which that locality is famous.

Southern termination of the fault.

A short distance to the south of Panghsa-pyé the fault dies out, no definite signs of its presence having been detected on the south side of the Nám-sam valley. This fact is in accordance with the supposition that the *locus* of the fault was determined by the presence of the old land area; for on the latitude of Panghsa-pyé the border of this area changes its direction, and trends away to the west, so that the 'anvil' effect of this unyielding mass of rock was not felt to the south of that neighbourhood.

Outliers of Námhsim Sandstone.

Several outliers of the Námhsim Sandstones occur on the eastern side of the overthrust, on the spurs running down to the western bank of the Nám-Tu, forming conspicuous knolls or ridges, with steeply scarped sides. The largest of these is on the Mán-wing—Mán-ping spur, just above these villages (Plate 22); another is found between Ngai-tao and Manglang on the next spur to the north; a third surrounds the village of Pangtawng, and a fourth occurs

on the spur to the north of this village. At the base of each the purple band is exposed, and in that of Ngai-tao there is a good exposure of the graptolite beds, as already mentioned (p. 128).

Fossil localities.

Fossils have been collected from the Námhsim Sandstones east of the Nám-Tang at the following localities:—Above the crest of the cliffs overhanging Kiohsiô (N), on the path to Ponglông (Loc. 53, E 2), a specimen of *Goniophora* (?) *asiatica* Reed, a new species of a genus ranging in America from the Trenton limestone to the Chemung group (Caradoc to Devonian), was found, together with badly preserved specimens of *Orthonota*, *Orthoceras*, and fragments of *Encrinurus*. A single specimen of a variety of an upper Llandovery form, *Lingula crumena* Phillips, named *birmanica* by Mr. Cowper Reed, was found close to the base of the formation at Hkyawngtawng (Loc. 50, E 2), on the Námhsim, in a tough brown sandstone, and a species of *Orthonota* somewhat higher up, on the path from Námmang to Ponglông (Loc. 51, E 2). This resembles *Cypricardia* (*Orthonota*) *solenoides* Sow., from the lower Ludlow. On the northern side of the peak marked 5,065 feet, on the path from Htangsang to Mán-tang (Loc. 57, E 2), between the Nám-non and Nám-sam valleys, I found a large number of specimens of *Illænus* sp. nov. aff. *æmulus* Salter, with fragments of other trilobites, in loose blocks of soft brown sandstone, and similar specimens of *Illænus* were also collected from the talus at the foot of the scarp opposite Lilu, on the Nám-Tu (Loc. 59, F 1). The fossils described by Mr. Cowper Reed as from Panghsa-pyé were collected by Dr. G. E. Pilgrim from near the base of the sandstones at the eastern end of the Panghsa-pyé saddle, where they rise above it to form a scarp overlooking the village (Loc. 65, F 2). This locality has produced three trilobites:—*Illænus* aff. *æmulus* Salter, a Llandovery species ranging from the Ordovician into the lower beds of the Silurian; *Calymene Blumenbachi* Brongn., a very well-known and characteristic Silurian species, represented by three fairly well preserved head shields; and *Phacops* (*Dalmanites*) *longicaudatus* Murch. var. *orientalis* Reed, a variety of another very characteristic Silurian species, differing only from the type in having the eyes relatively larger, and fewer pleuræ in the pygidium. This trilobite has since been found also at the Lilu and Mán-tang localities mentioned above.

Absent in Eastern Ranges.

The Námhsim Sandstones have not been found at all among the Eastern Ranges, either because they have been overlapped by the Plateau Limestone, and

denudation has not proceeded far enough to expose them, or, as in my opinion is the more probable explanation, because this portion of the sea floor was so remote from the coast of that period that the sandy beds were not deposited. I am the more inclined to adopt this view, because the marly, upper Námhsim beds are to be found in most parts of this area, and in places like the Loi-len range, where the covering of limestone has been stripped off over a very large extent of country, there is no sign of any thick bed of sandstone ever having been present beneath it.

Upper Namhsim Stage (Konghsa Marls).

Lithological characters and mode of deposition.

In places where the Námhsim Sandstones are well represented, as in the gorge of the Nám-Tu north of Hsipaw, and in that of the Námhsim above its conflux with the former river, they are found to be followed conformably by a band of sandy marls with layers or lenticular inclusions of very hard and compact limestone. These beds, though of no great thickness, have been found over a very wide area, extending far beyond the limits of the lower part of the formation. The reason for this comparatively wide extension of the marls appears to be, not that they were deposited in a sea basin gradually increasing in area, by subsidence of its shores, but that the sandstones beneath were laid down only in the neighbourhood of the coast. The marly beds, therefore, in localities where the sandstones are not represented, may be partly contemporaneous with the latter, that is to say, that while the sandstones were being laid down along the coast line, the marls were already being accumulated further out to sea, but naturally at a slower rate; and I think that this hypothesis is borne out by the palæontological evidence, which, as we shall see, does not indicate in any way whatever that the two classes of deposits were laid down at distinct periods of time.

List of fossils.

At several localities these beds are found to be richly fossiliferous, and in spite of their small thickness as compared with the sandstones, they have yielded a much larger number of species than the latter. The collections already made, and described by Mr. Cowper Reed in his Memoir on the lower Palæozoic fossils of the N. Shan States, comprise the following species:—

Actinozoa—

Lindstrœmia sp.

Bryozoa—

Fenestella sp.

Brachiopoda—

Lingula Lewisi (?) Sow.
Leptæna rhomboidalis Wilckens.
Strophomena(?) *corrugatella* Davidson var.
Orthothetes pecten Linné.
Orthis rustica Sow.
,, (*Bilobites*) *biloba* Linné.
,, (*Dalmanella*) *elegantula* Dalman.
,, (*Platystrophia*) *biforata* Schlotheim.
Pentamerus cf. *oblongus* Sow.
,, (*Sieberella*) cf. *galeatus* Dalman.
Conchidium cf. *biloculare* Linné.
Atrypa reticularis Linné.
Glassia cf. *compressa*(?) Sow.
Spirifer cf. *radiatus* Sow.
,, *sulcatus* Hisinger.
Rhynchospira (*Homœospira*) *Baylei*(?) Davidson.
Nucleospira pisum(?) Sow.
Meristella (?) sp.

Mollusca—

Pterinea **konghsaensis** Reed.
Conularia sp.
Orthoceras aff. *Nicholianum* Blake.

Arthropoda—

* *Encrinurus* **konghsaensis** Reed.
* *Calymene Blumenbachi* Brongn.
* *Cheirurus* cf. *bimucronatus* Murch.
Phacops **shanensis** Reed.

Annelida—

Trachyderma cf. *squamosa* Phillips.[1]

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* Occur also in the lower Námhsims.

[1] No additions have been made to this list by more recent work.

Paucity of new species.

The most striking feature about this list is the large number of species that have already been described, or are so closely allied to known forms that they do not require new names. Among the 24 determinable species Mr. Cowper Reed has found it necessary to give names to only three, whereas of the nine determinable species of the lower Námhsims four, or nearly half, were new. This greater similarity, however, in the fauna of the upper Námhsims to that of the Silurian fauna of other regions is perhaps more apparent than real, and may be due merely to a greater similarity of environment in the case of the upper beds, since these correspond more closely in lithological character to the calcareous beds of the Silurians of Europe.

Distribution: Western edge of Plateau.

The upper Námhsim beds have not been found close to the western edge of the plateau, but make their first appearance along the crest of the Pyinthá ridge, the second considerable rise on the way from the plains up to Maymyo. They may be present at the base of this ridge, about a mile east of Zebingyi station (Loc. 39, **B** 5), where an outcrop of the Zebingyi beds with graptolites is exposed in a low cutting, resting on some marly beds containing *Orthoceras* and the pygidia of *Phacops shanensis*, but the ground between this cutting and the base of the ridge is so overgrown with vegetation that nothing more can be seen of the rocks. At the top of the ridge the marls are exposed on the cart road in a dip at the 32nd mile just before reaching the village of Kyinganaing (Loc. 43, B 5). Here the only fossil found is the trilobite *Phacops shanensis* Reed, but it occurs in large numbers, and though the rock, a bright yellow marl, is exceedingly soft, the specimens, when first broken open, are quite well preserved, though the details are apt to be quickly rubbed off. The species belongs, according to Mr. Cowper Reed, to *Phacops sens. str.*, which is characteristic of the Devonian, but also occurs in the Silurian. A variety of *Ph. fecundus* Barr., from the 'Hercynkalke' of the Harz, is perhaps identical with this species. The pygidia of the same species are rather common in the cutting east of Zebingyi station mentioned above, and in a small exposure in a watercourse at the side of the cart road about a mile west of Pyinthá, just at the crest of the ridge.

Northern edge of Plateau.

Further on the marls have not been detected for a very long distance, probably because they are so apt to be eroded and concealed by surface wash and vegetation. The next place at which they are known to occur

is at the northern edge of the plateau, a little to the north of Pangyu (Loc. 46, **C** 3), where they form several low hills just outside the boundary of the Plateau Limestone. The beds here consist of hard, blue, compact limestones weathering into a soft, rotten, sandy marl, in which a few fossils were found. These included two species of *Orthoceras*, one of which is indeterminable, and the other is allied to *O. Nicholianum* Blake, an upper Silurian form, and a single specimen of an Annelid, comparable with *Trachyderma squamosa* Phillips, from the upper Ludlow beds.

Fossils.

In the Gokteik gorge the upper Námhsim beds are very poorly represented, only one small outcrop having been discovered, on the cart road leading up from Chaungzôn to the plateau on the east side, between the 88th and 89th mile posts, near the village of Pomaw (Loc. 48, **D** 3). The rock here is a soft, rotten, brown sand rock, probably representing the residue of a decomposed limestone, and the fossils are as usual in a very friable condition. Numerous specimens of a *Lindstrœmia*, resembling *L.* (*Petraia*) *subduplicata* McCoy, from the Llandovery beds of the British Isles, were collected here, and a new species of *Encrinurus*, *E. konghsaensis* Reed, which has also been found at several other localities in these beds. It occurs further to the north, for instance, at the head of the descent on the path from Makhinsuk to the Nám-Tang at Manná (Manna 1 of Mr. Cowper Reed's Memoir, p. 148), (Loc. 49, **D** 3) with fragments of another trilobite, *Cheirurus* cf. *bimucronatus* Murchison, a typical Wenlock form. These beds have not been found higher up the Nám-Tang, but in the north-south reach of the river south of Námsaw they are almost certainly cut out by a fault.

Gokteik gorge.

A very richly fossiliferous outcrop of these beds occurs close to the village of Kônghsá, in a cutting on the railway about a mile west of Kyaukmé station (Loc. 55, **E** 2). The rock here is a soft yellow marl, similar to that of Kyinganaing, and the fossils are in the same friable condition, but in much greater variety and very numerous. The collection includes :—Detached rings of crinoid stems, some of large size, and often hardened by an infiltration of iron oxide ; a species of *Fenestella*, consisting of—

Fossils, Kônghsá.

"A subcircular, slightly crateriform, reticulate expansion . . . . composed of straight, frequently bifurcating branches which radiate from the central

point of attachment . . . . . . connected together by somewhat more slender dissepiments, thus forming the fenestrules, which are oblong in shape and about twice as long as wide." (*Op. cit.*, p. 95, Pl. VI, figs. 1, 1*a*.)

This fossil is very common here, several specimens occurring on the same slab of rock. The brachiopoda comprise :—*Lingula Lewisi* (?) Sowerby, a Wenlock and Ludlow form in England; *Strophomena corrugatella* Davidson, var., a species which is chiefly Ordovician, though it has been recorded from the Llandovery of Ayrshire. The ornamentation also resembles that of *Leptæna* (*Str.*) *nobilis* McCoy, from the middle Devonian, and of *Str.* ( ) *St phani* Barrande, from Étage Ff 2 (upper Ludlow) in Bohemia; *Orthis* (*Platystrophia*) *biforata* Schlotheim, a species having a very wide range, extending from the Llandeilo to Wenlock beds in Northern Europe; *Orthis* (*Dalmanites*) *elegantula* Dalman, a species which also ranges from Ordovician to Silurian, and is common in the Naungkangyi beds. There is also a single lamellibranch, *Pterinea konghsaensis*, a new species having a considerable resemblance to *Pt. hians* McCoy, from the Aymestry Limestone; a species of *Conularia* of which only a single fragment was found, somewhat similar to the Silurian species *C. quadrisulcata* Sowerby; and lastly, a new species of trilobite, *Encrinurus konghsaensis*, resembling in some respects *E. punctatus* Brünnich, a well-known Silurian species. This species, as we have seen, has been found at other localities in these beds, as well as in the sandstones below.

Fossils, Manaw.

About six miles to the north of this locality, at the crest of the descent to the Námhsim, a mile and a quarter north of the village of Manaw, another rich assemblage of fossils was found, in a layer of pinkish, rather coarse-grained sandstone, not more than 6 inches thick, intercalated with somewhat shaly, purple and red sandstone (Loc. 52, **E** 2). The horizon of the fossiliferous band is probably rather lower in the series than the Kônghsá beds, but as the ground for a long distance on either side of the outcrop is covered with surface soil and vegetation, the exact position could not be ascertained. The fossiliferous band was evidently at one time impregnated with calcareous matter, but this has all been leached out, leaving the rock in a somewhat porous condition, and the fossils are all casts. They include numerous detached rings of crinoid stems, some of large size; *Leptæna rhomboidalis* Wilckens, a common and widely ranging Ordovician and Silurian species, known from Europe, America and

Australia; *Orthothetes* (*Strophomena*) *pecten* Linné, ranging in Europe from Llandovery to Wenlock; *Orthis rustica* Sowerby, a well-known Wenlock species; *Orthis* (*Bilobites*) *biloba* Linné, the most common form at this locality, whole slabs of the rock being crowded with them: the species ranges from Bala to Ludlow, and is especially common in the Wenlock shales; the ubiquitous *O.* (*Dalmanites*) *elegantula*; *Pentamerus* cf. *oblongus* Sowerby, comparable with the well-known Llandovery form, also occurring in the Niagara (Wenlock) group of America; and *P.* (*Sieberella*) cf. *galeatus* Dalman, resembling some of the examples from the Wenlock limestone and shale figured by Davidson[1]; *Conchidium* cf. *biloculare* Linné, resembling, though poorly preserved, this Silurian species from Gotland; *Atrypa reticularis* Linné, a very common Silurian and Devonian species, also known from China, remarkable for its wide vertical range and geographical distribution, and represented here by both internal and external casts; *Spirifer* cf. *radiatus* Sowerby, a common fossil in the Wenlock limestone of Dudley, and *Sp. sulcatus* Hisinger, a typical Wenlock species; *Glassia* cf. *compressa* Sowerby, also a typical Wenlock and Ludlow form, but the Manaw specimen is identified with much hesitation by Mr. Cowper Reed with Sowerby's species; *Rhynchospira* (*Homœospira*) *Baylei* (?) Davidson, a common form in the Wenlock limestone, represented by only one external cast; *Nucleospira pisum*(?) Sowerby, a characteristic Wenlock species, from which the specimen found at Manaw seems to be indistinguishable; and finally a species of *Meristella*, referred with some hesitation to this genus, and bearing some resemblance to *M. Maclareni* Haswell, from the Ludlow beds of the Pentland hills, or to *M.* (*Whitfieldella*) *didyma* Dalman, which ranges from the Llandovery to Ludlow.

Comparison of Kôngh-sá with Manaw fauna.

It will be noticed that not one of the species enumerated above from Kôngshá and from Manaw are common to the two localities, except *Orthis elegantula*; also that of the 15 species from Manaw no less than 14, either identical or very closely related, are found elsewhere in the Wenlock formation, and that 7 of these are characteristic of that formation; while, of the 10 species from Kônghsá, only 4 or 5 are recorded from Wenlock beds, and not one is a typical form. At the same time the stratigraphical evidence is entirely against there being any great difference in the relative horizons of

[1] Brit. Foss. Brachiopoda, Pl. XV, figs. 17, 18.

the outcrops at the two localities, and the discrepancies can only be accounted for by local variation in environment. This is also indicated by the apparently very restricted distribution of the Manaw fauna, which has been met with only in this one locality, and by the very small thickness of the layer in which this fauna is contained. But it is easy to see how such a thin band of rock might escape detection in a district where the rocks are so concealed by superficial deposits as they are on the Shan plateau, and such a discovery as this, due one may say to an accidental blow of the hammer, shows how much there is still to be learned by patient search, before the relationships of the isolated outcrops described in this Memoir can be worked out.

North-easterly extension.

The upper Námhsim beds have been recognised on the eastern slopes of the hills north-west of Hsipaw, on the path to Panghsa-pyé, above the village of Mán-hpeklu (**F** 2), but only fragments of trilobites and small brachiopods were found here. They also occur along the crest of the scarp east of the Nám-Tu gorge, further to the north, and are seen just above the mouth of the Nám-pang-yun or Bawdwin river, where they contain large numbers of *Orthis elegantula;* but the beds are generally much concealed, and no fossiliferous localities comparable to those of Kônghsá or Manaw have been found in this direction. Indications of the presence of these beds are to be seen, however, in almost every instance when the boundary between the Námhsim Sandstones and the Plateau Limestone is crossed, and in spite of its small thickness, the band seems to be remarkably persistent.

Eastern Ranges.

The same remarks apply to the development of these beds in the Eastern Ranges. They are to be met with whenever the boundary between the Plateau Limestone and the underlying rocks is exposed, though the thick Námhsim Sandstones appear to be absent in this area. Fossils are not numerous, but specimens of the *Fenestella* so abundant at Kônghsá were found in more than one place along the crest of the Loi-len range, and also further to the north-east, near the village of Panghsa-pui (Loc. 61, **I** 1) These beds are found all along the eastern base of Loi Ling, forming a narrow fringe at the edge of the limestone plateau, and in the dome-shaped range of hills to the east, between the Tertiary coal-field of Mán-se-lé and the plateau of Möng-Keng, they occupy very large areas both

Loi Len Rang.

Möng-Keng dome.

at the northern and southern ends of the dome, arching over the purple Hwe Mawng shales forming its core. In the northern area a great thickness of beds is exposed, and it is possible that the Námhsim Sandstones, as well as the marls, are represented here, but this tract of country has only been cursorily examined. A few fragments of trilobites, probably of *Encrinurus*, were the only fossils detected. At the southern end the rocks are very sandy and friable in texture, breaking down easily into a loose sand forming rounded pine-clad hillocks, among which it is hopeless to search for natural outcrops.

Hills east of Möng-Yai.

To the south also the beds are of this soft, sandy texture, and are very seldom exposed as solid rock. In fact, it would be almost impossible to map their boundaries with the Plateau Limestone, were it not for the circumstance that the common pine of this region, *Pinus Khasya*, does not grow naturally on the limestone, but is found in great numbers wherever the soil is of a sandy character. The outer edge of the pine forests is therefore an excellent guide in mapping this boundary, while the inner boundary with the Hwe Mawng beds may generally be detected with a certain degree of accuracy, since the latter are harder, rise more abruptly from the low ground, and afford numerous outcrops. In this way the upper Námhsim beds have been traced along the western edge of the hills south of Loi Ling, in South Hsenwi, up the valley of the Nám Há, and along the eastern edge of the hills in the valley of the Nám Pang. The graptolites, *Monograptus priodon* and *Cyrtograptus* sp., already mentioned (p. 129) as occurring at Kanlun in the valley of the Nám Há (Loc. 69, **I** 3), may perhaps belong to this horizon; but the rocks containing them are not of the same type as the marls, being more shaly, with carbonaceous layers, overlying a band of hard limestone. The exposure is quite isolated, and its position with regard to the rocks above and below could not be ascertained. In the band along the edge of the hills bordering the Nám Pang fossils were found at two localities:—*Lindstrœmia* sp. and numerous specimens of an undetermined bryozoan at Námpung, in the bed of a stream of the same name close to the village (Loc. 62, **J** 3); and the same coral, with fragments of trilobites, probably *Phacops shanensis* Reed, and brachiopods, all reduced to powder by the leaching out of the calcareous matter from the rock, near the small village of Ho-hkô, not marked on the quarter inch map

(Loc. 63, **J** 4), on the path from Pa-tep to Mong-Heng, in the Nám Há valley.

Loi Twang range.

The upper Námhsims also occur along both sides of the Loi Twang range, in Kehsi Mansam and Möng Küng, but their presence is usually only to be detected by the low mounds of loose sand into which they break up, and outcrops of solid rock are very seldom seen. A few specimens of *Phacops shanensis* Reed, the species that is so abundant at Kyinganaing, near the western edge of the plateau, were found in a small outcrop in the Nám Ká, about half a mile north-west of Hamngai, in the state of Möng Küng, on the eastern side of the range (Loc. 60, **G** 5).

Range and distribution of species.

The homotaxial relations of the fauna of the Námhsim formation with that of other regions are summarised in Tables 4 and 5, a new species being printed in heavier type, and those which are found in both divisions of the formation being marked by an asterisk :—

TABLES 4 AND 5.

List and Distribution of Námhsim Fauna.

TABLE 4.

List and Distribution of

NOTE:—In Tables 4 and 5 the following abbreviations are used:—

Lw. = Ludlow = U. Oesel zone, U. Gotlandian, *N. Europe* = Étage F, *Bohemia* = L. Helderberg group, *N. America.*

Wk. = Wenlock = L. Oesel zone, L. Gotlandian, *N. Europe* = Étage E 2, *Bohemia* = Niagara group, *N. America* = Hayden's Horizons 7 and 8, Himalayas.[1]

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRACHIOPODA.	
Lingula crumena Phill. var. **birmanica** Reed.	Ord.-Recent, Cosmopolitan
Mimulus **aunglokenis** Reed.	U. Sil., Europe, N. America
Orthis (?) sp.	Ord.-Carb., Cosmopolitan
PELECYPODA.	
Orthonota(?) **spectabilis** Reed.	Sil., Europe Dev., N. America
,, (?) sp.	Ditto

[1] Geology of Spiti, *Memoirs Geol.*

Lower Namhsim Fauna.

Ly. = Llandovery = Pentamerus beds, *N. Europe* = Étage E1. *Bohemia* = Clinton group, *N. America*.
Cc. = Caradoc or Bala = Kuckers beds and Cystidean Limestone, *N. Europe* = Étage D 4, D 5, *Bohemia* ‖ Trenton group, *N. America*.

Nearest Allies.	Horizon and Distribution of Species or nearest Ally.							Remarks.
	N. Europe.	Great Britain.	Bohemia.	N. America.	Himalaya.	Central China.	Australia.	
—	..	U. Ly.	..	..	..	..	..	
M. contrarius Barr.	..	..	Wk.	..	..	..	..	
M. waldronensis Miller and Dyer.	..	..	..	Wk.	..	..	..	
Streptis Grayi Dav.	Wk.	Wk.	..	Wk.	..	..	..	
—	..	..	..	..	..	..	..	Occurs with *Mim. aunglokensis*.
Sanguinolites (*Orthonota*) *decipiens*, McCoy.	..	U. Lw.	..	..	..	..	..	
(?) *Cypricardia* (*Orthonota*) *solenoides* Sow.	..	L. Lw.	..	..	..	..	..	

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TABLE 4—*contd.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
GASTROPODA.	
Pycnomphalus (?) sp.	Sil.-Dev., Europe
CEPHALOPODA.	
Orthoceras aff. tenuiannulatum McCoy.	Ord.-Trias, Cosmopolitan
ARTHROPODA.	
Illænus aff. æmulus Salter.	Ord.-Sil., Cosmopolitan
Proetus sp. α.	Ord.-Carb., Cosmopolitan
„ sp. β.	Ditto
* Calymene Blumenbachi Brongn.	Ord.- Sil., Cosmopolitan
* Cheirurus cf. bimucronatus Murch.	Ditto
* Cheirurus(?) inexpectans Reed.	Ditto
* Phacops (Dalmanites) longicaudatus var. orientalis Reed.	Ord.-Dev., Cosmopolitan

Lower Namhsim Fauna—*contd.*

Nearest Allies.	N. Europe.	Great Britain.	Bohemia.	N. America.	Himalaya.	Central China.	Australia.	Remarks
	Horizon and Distribution of Species or nearest Ally.							
Trochus helicites, Sow.	..	U. Lw.	..	..	..	..	..	
T. acutus Lindst.	Lw.	..	..	..	..	..	..	
(?) *Euomphalus* sp.	..	..	..	..	..	?L. Ly.	..	Kian-tshang-pa (Kayser).
—	..	Lw.	..	..	..	..	..	
—	..	Cc.-Ly.	..	..	..	..	..	
Pr. Fletcheri Salter.	..	Wk.-Lw.	..	..	..	..	..	
—	..	..	..	..	..	..	..	
—	Wk.	Cc.-Lw.	Wk-Lw	Cc.-Wk.	..	..	U. Ly.	N. S. Wales.
—	..	Cc.-Lw.	..	..	..	..	..	
Ch. vinculum Barr.	..	..	Cc.	..	..	..	..	
Ph. longicaudatus Murch.	..	Wk.-Lw.	Wk.	..	..	..	U. Sil.	Victoria.

TABLE 5.

List and Distribution of

NAME	RANGE AND DISTRIBUTION OF GENERA.
ACTINOZOA.	
Lindstrœmia sp.	Ord.-Carb., Europe, Dev., N. America
BRYOZOA.	
Fenestella sp.	Ord.-Carb., Cosmopolitan
BRACHIOPODA.	
Lingula Lewisi Sow.	Ord.-Recent, Cosmopolitan
Leptæna rhomboidalis Wilck.	Ord.-Carb., Ditto
Strophomena(?) corrugatella Dav. var.	Sil.-Carb., Ditto
Orthothetes pecten Linné.	Ditto Ditto
Orthis rustica Sow.	Ord.-Carb., Ditto
„ (Bilobites) biloba Linné.	Sil., Europe, N. America
„ (Platystrophia) biforata Schloth.	Ord.-Carb., Europe, N. America
„ (Dalmanella) elegantula Dalman.	Ord.-Dev., Cosmopolitan

Upper Namhsim Fauna.

Nearest Allies.	Horizon and Distribution of Species or nearest Ally.							Remarks.
	N. Europe.	Great Britain.	Bohemia.	N. America.	Himalaya.	Central China.	Australia.	
Petraia subduplicata McCoy.	..	Cc.-Wk.	..	..	..	..	..	
—	..	..	..	..	..	..	..	
—	Lw.	Lw.	..	..	..	..	..	
—	Wk.-Lw.	Cc.-Carb.	Wk.-Lw.	Cc.-Dev.	Wk.	..	U. Sil.	N. S. Wales.
—	..	Lo.-Ly.	..	..	..	?Ly.	..	Kian-tschang-pa (Kayser).
—	Wk.	Ly.-Wk.	..	Wk.	..	..	U. Ly.	N. S. Wales.
—	Wk.	Wk.	..	..	Wk.	..	..	
—	Wk.	Cc.-Lw.	..	Cc.-Wk.	..	..	..	
—	Lo.-Wk.	Cc.-Wk.	..	Cc.	..	..	..	
—	Cc.-Wk.	Lo.-Lw.	Ly.-Wk.	Wk.	Wk.	..	Sil.	

TABLE 5—*contd.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRACHIOPODA—*contd.*	
Pentamerus cf. oblongus Sow..	Sil., Cosmopolitan . . . . .
,, (Sieberella) cf. galeatus Dalman. .	Sil.-Dev., Europe, N. America . . .
Conchidium cf. biloculare Linné . . .	Sil.-Dev., Cosmopolitan . . .
Atrypa reticularis Linné	Sil.-Dev., Cosmopolitan . . . .
Glassia cf. compressa Sow.	Sil.-Dev., Europe, N. America . .
Spirifer cf. radiatus Sow.	Sil.-Carb., Cosmopolitan . . . .
,, sulcatus His.	Ditto . . . . . .
Rhynchospira (Homœospira) Baylei(?) Dav. .	Sil., N. Europe, N. America . . .
Nucleospira pisum(?) Sow.	Sil.-U. Dev., Europe, N. America . .

Upper Namhsim Fauna—*contd.*

Nearest Allies.	N. Europe.	Great Britain.	Bohemia.	N. America.	Himalaya.	Central China.	Australia.	Remarks.
	Horizon and Distribution of Species or nearest Ally.							
—	Ly.-Wk.	Ly.	..	Ly.-Wk.	Wk.	..	Ly.	N. S. Wales, S. Australia.
—	Wk.-Lw.	Wk.-Dev.	Lw.	Lw.	..	..	..	
—	Wk.	..	..	..	..	..	..	
—	Wk.-Dev.	Ly.-U. Dev.	Wk.-Lw.	Ly.-U. Dev.	..	?L. Ly.	U. Lw.-M. Dev.	N. S. Wales, Victoria. Kian-tshang-pa (Kayser).
—	..	Wk.	Wk.-Lw.	..	..	..	..	
—	Wk.-Lw.	Wk.-Lw.	..	Ly-Wk.	..	..	..	
—	Wk.-Lw.	Wk.	Wk.-Lw.	Wk.	..	..	..	
Sp. elevatus Dalman.	Wk.	Ly.-Lw.	..	..	..	Sil.	..	Tshan-tiën (Kayser).
—	..	Wk.	..	..	..	..	..	
Retzia Salteri Dav.	Wk.	..	..	..	..	..	..	
—	Wk.	Wk.	..	..	..	..	..	
N. pisiformis Hall.	..	..	..	Ly.-Wk.	..	Sil.	..	Tshan-tiën (Kayser)

TABLE 5—*concld.*

List and Distribution of

NAME.	RANGE AND DISTRIBUTION OF GENERA.
BRACHIOPODA—*concld.*	
Meristella(?) sp.	Sil.-Dev., Europe, N. America
PELECYPODA.	
Pterinea **konghsaensis** Reed.	Sil.-Carb., Cosmopolitan
PTEROPODA.	
Conularia sp.	Ord.-Trias, Cosmopolitan
CEPHALOPODA.	
Orthoceras aff. Nicholianum Blake.	Ord.-Trias, Cosmopolitan
ANNELIDA.	
Trachyderma cf. squamosa Phill.	Sil., England
ARTHROPODA.	
* Encrinurus **konghsaensis** Reed.	Ord.-Sil., Cosmopolitan
Phacops **shanensis** Reed.	Sil.-Dev., Cosmopolitan

Upper Namhsim Fauna—*concld.*

Nearest Allies.	Horizon and Distribution of Species or nearest Ally.							Remarks.
	N. Europe.	Great Britain.	Bohemia.	N. America.	Himalaya.	Central China.	Australia.	
M.(?) *Maclareni* Haswell.	..	Lw.	..	..	..	..	..	
Pt. hians McCoy.	..	Lw.	..	..	..	..	..	
Avicula reticulata His.	Wk.-Lw.	..	..	..	..	..	..	
C. quadrisulcata Sow.	..	Lw.	..	..	..	..	..	
C. cancellata Sandb.	Lw.	..	..	..	..	.	..	
—	..	Ly.-Lw.	..	..	..	..	..	
—	..	U.-Lw.	..	.	..	..	..	
E. punctatus Brünn.	Wk.	Wk.-Lw.	..	..	Wk.	..	Lw.	N. S. Wales
Ph. fecundus Barr.	..	..	Wk.-L.Dev.	..	..	..	..	
Ph. Crossleyi E. and M.	.	..	..	..	..	..	?Wk.	N. S. Wales.
Ph. Sweeti E. and M.	..	..	..	..	..	..	U. Sil.	Victoria.

Homotaxial relations of the fauna.

A study of these tables shows that, in the present state of our knowledge, the fauna of the Námhsims must be taken as a whole, and that it is not possible as yet to subdivide the formation on palæontological grounds alone into zones corresponding with those in other countries. Among the 15 species that have been collected from the lower Námhsims 6, or their nearest allies, are found in the Wenlock beds of England, or their equivalents elsewhere, and 9 range as high as the Ludlow; while, in the upper Námhsims, among 28 species, 21 are found in the Wenlock, and only 18, including 13 which also occur at lower horizons, are Ludlow forms. Other anomalies may be noticed; for instance, *Pentamerus* cf. *oblongus* and a *Lindstrœmia*, closely allied to, if not identical with, *L.* (*Petraia*) *subduplicata*, both characteristic Llandovery forms in England,—though in America the former is found at a higher horizon,—are found here in the upper beds; and on the other hand *Orthonota*, which is a typically upper Ludlow shell, occurs low down in the lower division. At the same time we have genera and species like *Mimulus*, *Phacops longicaudatus*, *Orthis rustica*, *O. biloba*, *Conchidium biloculare*, *Spirifer sulcatus*, and *Nucleospira pisum*, which are characteristically Wenlock, and it is evident from a glance at the table that an overwhelming majority of the species occur in this formation, either in England or in its equivalents elsewhere. The formation then, taken as a whole, may be considered to be homotaxial with the middle Silurian or Wenlock beds, but with an admixture of species from higher and lower horizons. In order to account for the presence of these we require to know more about the geology of intervening regions. It may be remarked, however, that only 10 species occur also in Bohemia and 6 of these are wide-ranging forms like *Calymene Blumenbachi*, *Leptæna rhomboidalis*, *Orthis elegantula*, *Pentamerus galeatus*, *Atrypa reticularis*, and *Spirifer sulcatus*. As Mr. Cowper Reed remarks :—

"We observe the presence of many species of brachiopods allied to or identical with those found in beds of Wenlock age in Northern and Western Europe, in fact there seem to be very few peculiar or local species. The only discordant element is *Mimulus*, which is a Bohemian and American genus." (Lower Pal. Fossils, N. Shan States, p. 152.)

Himalayan equivalents.

When we compare this fauna with the Silurian fauna of Spiti and the Central Himalaya, as described by Mr. Cowper Reed in a recent Memoir,[1] the same almost absolute want of concordance becomes manifest as in the case of the Ordovician fauna; while the discrepancy existing in the relations of the species with those of America and Europe respectively is still more strongly marked than in the case of the older strata. While the 35 species described by Mr. Cowper Reed from the Silurian of the Central Himalaya are allied with those of America and Europe in practically equal proportions, 18 (51 per cent.) being common to the former province and 17 (49 per cent.) to the latter; out of the 40 species described from Burma by the same author no less than 35 (87·5 per cent.) are identical with or allied to European forms, and only 14 (35 per cent.) to American. Seven only are common to the Himalaya and Burma, all of these being ubiquitous species like *Orthis elegantula*, *O. calligramma*, *O. rustica*, *Leptæna rhomboidalis*, and *Pentamerus oblongus*; while only one of the species peculiar to Burma, *Encrinurus konghsaensis*, is represented by an allied species in the Himalaya, *E. punctatus*, also a widely ranging fossil.

Composition of the fauna.

The contrast in the composition of the Burmese and Himalayan Silurian faunas is also quite as striking as in the case of the Ordovician. The presence of graptolites is in itself sufficient to show that there could have been no direct communication between the two areas in Silurian times; for the character of the rocks of that age described by Mr. Hayden in Spiti (*Op. cit.*, p. 24) would not lead one to suppose that the conditions were not suitable for the growth and preservation of these organisms, if they had penetrated to that area. Again, the distinctive characteristic of Hayden's horizon 6, at the base of the Silurian in Spiti, is the preponderance of corals, no less than 13 species having been obtained from this horizon alone, of which 10 possess marked American affinities. In Burma, on the other hand, *Lindstrœmia* is the only Silurian coral yet found. In the higher horizons of Spiti there is a more varied assemblage of fossils, but even among the brachiopoda there is no close or peculiar connection with those of Burma, only the most widely ranging forms being represented in

[1] The Ordovician and Silurian Fossils of the Central Himalaya, *Palæont. Ind.*, Vol. VII, Mem. No. 2; *also* H. H. Hayden, The Geology of Spiti, with parts of Bashahr and Rupshu, *Memoirs, Geol. Surv. Ind.*, Vol. XXXVI, Pt. 1.

both areas; and there is certainly a greater variety of trilobites in Burma, as well as a much greater profusion of individuals. Whatever may have been the nature of the barrier, then, that separated the Burmese and Himalayan life-provinces in Ordovician times, it seems to have remained unsurmountable by marine organisms until the close of the Silurian epoch.

CHAPTER VIII.

SILURIAN SYSTEM.

Zebingyi Stage.

Nomenclature.

The next formation to be dealt with is perhaps one of the most interesting to be found in the whole of the Shan States, although it is very restricted in area, and of slight thickness, even where it is most highly developed. The name of Zebingyi beds, given to it in the reports drawn up by Mr. Datta and myself in 1900, is taken from a well known station on the railway between Mandalay and Maymyo, where the traveller first begins to realise that he has left the torrid plains of the Irrawaddy valley for the cool breezes of the uplands. It was in a cutting on the railway then under construction, about a mile west of the station, that I made my first assault upon the rocks of this region, on the 13th December 1899, and I can well recall the thrill of delight and astonishment with which I recognised, in the first fossiliferous piece of rock that I broke off, a fragment of a graptolite, the first of that class of organism that had been discovered in Southern Asia. It was this discovery that led me to suspect, at the very beginning of my investigations, that the geology and the fossil fauna of the Shan States would be found to differ, in a remarkable degree, from anything that was hitherto known in India; and though it perhaps gave at the outset a certain bias to my opinions, it can hardly be doubted, I think, that subsequent researches, those of the geologists who have been associated with me in this work as well as my own, have tended to confirm this view. I propose to return to this subject when the nature of the beds, their distribution, and the fauna contained in them have been described.

Discovery of graptolites.

M 2

Section of Zebingyi scarp (Section I, Plate 23).

The most complete section of these beds yet found is to be seen in the cuttings on the railway just before reaching the small plateau in the centre of which Zebingyi stands (B 5). After surmounting the zig-zags above Sedaw, the line still ascends a series of high gradients, with many sharp curves, along the crest of the scarp overhanging the valley of the Sedaw river, passing first through highly inclined Naungkangyi beds, and then through nearly horizontal Plateau Limestone, a poor outcrop of the Zebingyi beds, which we need not take further notice of now, being cut through at the point of junction. There is then a short level stretch of limestone, just beyond which, at the base of the low scarp bordering the Zebingyi plateau, there is a fault, and the beds are repeated. Ascending the line from this point we have, first a poor exposure of the Naungkangyi, or perhaps Nyaungbaw beds, somewhat contorted at the lower end of the section, and irregular in dip; then a series of grey limestones, in thin bedded, regular layers dipping gently to the east-north-east or north-east, containing numerous specimens of *Orthoceras* and an occasional trilobite. With these are intercalated more shaly, carbonaceous layers crowded with *Tentaculites*. Higher up the limestones are in thin regular bands, separated by thicker layers of light coloured shale. The whole thickness of these limestones and shales may be about 200 feet, but owing to the irregularity of the dip, and the frequent curves taken by the railway, it was impossible to measure it accurately, while on either side of the line the slopes are covered with almost impenetrable jungle, so that no measurements can be made along a direct line. The grey flaggy limestones are followed by about 80 feet of dense black, somewhat earthy limestone, with thin partings of black shale, in which the graptolites occur, associated with enormous numbers of *Tentaculites elegans* Barrande (Loc. 38, B 5).

The fossils collected at this locality were:—

Fossils: Graptolite beds.

In the black limestones; *Monograptus dubius* Suess, a Wenlock and lower Ludlow species, "characterised by possessing thecæ of one type only, by the outer wall of the first theca extending down to the aperture of the sicula and inclined to it at a small angle (20° to 30°), and by the length of the adult theca being as a rule two or three times the width . . . . Miss Wood in describing the species remarks

that it is typically a Wenlock form but that it occurs as high as the zone of *M. scanicus* of the lower Ludlow shales" (Lower Pal. Fossils, N. Shan States, page 91). Also *Tentaculites elegans* Barr., agreeing in every respect with specimens from Bohemia. The fossils are of small size, averaging 3-4 mm. in length, but some reach a length of 7-8 mm.

"They are slender, conical shells, tapering at first rather slowly, and then more rapidly towards the apex, with regular, equal, and equidistant rings, separated by rather wider interspaces; a fine longitudinal lineation also ornaments the shell, and is most distinct in the interspaces. Most of the specimens are more or less crushed, but nearly all have a longitudinal groove or depression extending from the mouth to about half-way down one side of the shell, and it seems to be a constant feature (as in *T. cancellatus* Richter), and not the result of accidental injury. It is represented in Barrande's figure,[1] but no comment is made upon it." (*Op. cit.*, p. 125.)

The species is believed by Kayser to be identical with, or only a variety of, *T. acuarius* Richter, which occurs in the Harz in Silurian beds, associated with *Favosites gotlandica*, *Cardiola interrupta*, etc., but Barrande mentions some important distinctions between the two species. In Bohemia *Tentaculites elegans* ranges from Ét. F 2 to H 1, and is therefore a Devonian species. Besides these a small Pteropod, comparable with *Styliolina lævis* Richter, from the Nereites beds (Lower Silurian) of the Thüringer Wald, also occurs in the black limestone.

Fossils: Flaggy limestones.

The fossils found in the grey limestones and associated shaly bands comprised: — *Vlasta* sp., a small strongly ribbed shell with a large incurved beak, resembling *V. tumescens* and *V. bohemica* Barr., both from Et. E 2 (Wenlock) of Bohemia. A form comparable with *V. tumescens* has also been recorded by Tschernychew from the lower Devonian of the Urals; *Orthoceras* aff. *commutatum*, a lower Devonia species of the Harz, allied to *O. distans* Sow., from the lower Ludlow of England, and another species with more numerous and more closely placed septa. *O.* aff. *mocktreense* Sow., a specimen of which, from another locality, has been described and figured by Mr. Cowper Reed (*Op. cit.*, p. 127, Pl. VII, fig. 9), also occurs here as I found on my last visit to Zebingyi, when I obtained a fine specimen. It is an upper Ludlow form, but sometimes occurs in the Wenlock. Other genera and species of Cephalopoda are also

[1] Syst. Silur. de la Bohême, Vol. III, Pl. XIV, figs. 20—27.

represented in the grey limestones, for I have found sections of forms showing septa resembling those of *Ascoceras* on the surface of the rock, but it is impossible to extract the entire fossil.

Phacops Swinhoei.

A very fine specimen of a large trilobite, *Phacops* (*Dalmanites*) *Swinhoei* Reed, was found by me in a loose block weathered out from a bed of dark grey limestone just below the graptolite horizon. This has been figured by Mr. Cowper Reed in his Memoir (*Op. cit.*, fig. 3, p. 140), the figure showing the pygidium, which is almost perfect, and a part of the head shield. It is very closely allied to *Ph.* (*Dalmanites*) *Hausmanni* Brongn., which occurs in Ét. G (lower Devonian) in Bohemia, and belongs to a group of species characteristic of this horizon in southern Europe. Mr. Cowper Reed remarks—

> "It is represented in the 'Hercynkalke' of the Harz by *Ph.* (*Dalmanites*) *tuberculatus* Rom. The occurrence of this type in the Burmese Silurian is thus an important indication of the affinities of the Zebingyi beds."

Since this specimen was found, I have searched the locality carefully for more specimens, in company with my friend Mr. Swinhoe, of Mandalay, who was with me when I found the example figured, and has more than once visited the spot on his own account, but neither of us has succeeded in finding more than mere fragments of other individuals. I have, however, obtained a few specimens, though poorly preserved, of another and smaller species of *Dalmanites*. The locality is easily accessible, it being possible to get to it by train from either Mandalay or Maymyo in the morning and return the same evening, and as the weathering of the rock proceeds very rapidly in the moist climate of these hills, the extraction of the fossils will doubtless become more easy as time goes on.

Passage into Plateau Limestone.

The black limestones are succeeded by a series of flaggy, white, thin bedded limestones, with the same gentle but irregular north-easterly dip, which pass upward into the ordinary crushed type of the Plateau Limestone, the passage being apparently quite conformable. In these flaggy limestones no fossils whatever have been found, and higher up, in the crushed limestone, the only traces of organisms are small joints of crinoid stems, while even these are rare.

Zebingyi synclinal.

Beneath the Zebingyi plateau the rocks form a shallow synclinal, bending up again to the east with a westerly dip, so that, about a mile to the east of the station, the graptolite beds reappear from beneath the Plateau Limestone. The section here (Zebingyi 2 of Mr. Cowper Reed's Memoir) (Loc. 39, **B** 5) is a very poor one, exposed partly in a small cutting, and partly in the drainage channels on either side of the line, and differs in some respects from that west of the station. The black earthy limestones are very much diminished in thickness, and most of the graptolites occur in light grey shales, but they are in a better state of preservation and more numerous than at the former locality. The grey thin-bedded limestones and shales beneath them have also disappeared, and the only limestone to be seen is a hard, nodular, lenticular mass, crowded however with casts of *Orthoceras*, but so completely weathered that most of them crumble into dust on being extracted. The fossils collected here were:—In the graptolite shales,

Fossils.

Monograptus dubius; *Meristina sp.*, a transversely oval shell referred with some doubt to this genus, which is a Niagara or Wenlock form; an undetermined species of *Modiolopsis*; abundant specimens of *Tentaculites elegans*; and a single example of another species, compared with *T. ornatus* Sow., from the Wenlock beds of England. The rings on this species are fewer in number and wider apart than in *T. elegans*, and the interspaces are broad and marked with fine concentric striæ. The fossils collected in the underlying limestone were *Lindstrœmia* sp., similar to those found at Pomaw in the Gokteik gorge, and the same species of *Orthoceras* that occur at the locality below Zebingyi including the specimens of *O.* aff. *mocktreense* and *O.* aff. *commutatum* figured in Mr. Reed's Memoir (Pl. VII, figs. 9, 11, 12). The limestone also contains the pygidia of a small trilobite, probably of *Phacops shannsis* Reed.

Limits of outcrops.

The axis of the Zebingyi synclinal is inclined to the north in such a manner that the outcrop of the Zebingyi beds describes an elliptical curve, extending southwards to the village of Pebin, between Zebingyi station and the Mandalay-Maymyo cart road. At Pebin the beds are very thin, and they evidently died out rapidly in this direction. The northern side of the Zebingyi plateau is bounded by inaccessible cliffs of limestone, at the base of which in the Sedaw

valley, there is almost impenetrable jungle, and the only traces of the presence of the Zebingyi beds at the base of the limestone are fragments of the black shales with *Tentaculites elegans*, which may be picked up in the talus. They have not been detected on the north side of the Sedaw valley, where there is an outlier of the overlying limestone.

Crest of Pyinthá ridge.

The graptolite beds are exposed in several places near the crest of the ridge east of the Zebingyi plateau, forming a narrow band running roughly parallel to the cart road from Pyinthá northwards. A poor exposure is seen in a water-course close to the crest of the ridge about a mile south-west of the village, but a better one occurs in the stream that crosses the road at the village, and about half a mile above the crossing (Loc. 44, **B** 5). The beds here consist of shaly black limestones dipping E. 20° N. at about 18 degrees, and contain *Tent. elegans* and graptolites in large numbers. The latter are in a rather better state of preservation than at Zebingyi, and besides *Monograptus dubius* another species, *M.* cf. *riccartonensis* Lapworth, occurs, a species characteristic of one of the zones in the Wenlock beds of the Welsh borderland. The outcrop extends for some two or three hundred yards along the stream bed, and at the lower end of it some rotten argillaceous rocks were found containing trilobite fragments, probably of *Phacops shanensis*, but too soft and friable to be worth carrying away.

Extension northwards.

The black limestones crop out on the cart road itself just beyond the 29th mile, and then follow the crest of the ridge to within a short distance south of Kyinganaing, crossing the road again at the 32nd mile (Loc. 43, 5). Here the black limestones have disappeared, and the beds are very soft, pink and lilac coloured clays, but containing enormous numbers of *Tent. elegans*, crowded together on the bedding planes in the utmost profusion. Fifty or more can frequently be counted, according to Mr. Cowper Reed, in an area of 20 sq. mm. A mile further on the band, in the same clayey condition, crosses the road a third time, and then runs diagonally across the slopes towards Thondaung station.

Section at Thondaung (Fig. 5).

At this locality (Waboyé of Mr. Cowper Reed's Memoir), the Zebingyi beds are exposed in two places. A poor outcrop of the black shales with *Tent.*

elegans is seen about 100 yards to the north of the station, in a low cutting and in a 'borrow pit' east of the line, and is overlaid by the Plateau Limestone; then comes a deep cutting, in which the underlying Nyaungbaw beds, brought up by a fault, are exposed, dipping to N. 30° E. at 52 degrees. At the northern end of this cutting the Zebingyi beds appear again, dipping in the same direction, and resting upon the denuded edge of the underlying beds (Loc. 42, **B** 5, Plate 9). The shales at the base of the Zebingyi beds are ferruginous and do not contain many

FIG. 5. Section at Thondaung Railway Station.

N. Nyaungbaw Beds: Z. Zebingyi Beds: P. L. Plateau Limestone: *f* Fault.

Length of Section about 1 mile. Not drawn to scale.

Fossils.

fossils, but a few specimens of *T. elegans* were found in them. The black shales follow, intercalated with red earthy shales, exposed in a large 'borrow pit' at the side of the line, both containing the usual profusion of *Tentaculites* and large graptolites. A species of *Monograptus*, reaching a length of four or five inches, is very common here, but is not well enough preserved for identification. Two species of *Modiolopsis* were also found, one of which, *M. shanensis* Reed, is well preserved and is compared by Mr. Cowper Reed to *M. simplicissima* Barr., from Ét. E 2 of Bohemia. The other species is the same as that found at Zebingyi, but the only specimen collected is not in so good a state of preservation.

Thondaung to Naungkangyi.

From Waboyé the Zebingyi band runs along the crest of the scarp bordering the Sedaw valley, and is visible in the beds of the streams that cross the railway between Thondaung and

Ani Sakán stations. It is especially well seen close to Twinngé (Loc. 41, **B** 5), where specimens of *Monograptus dubius* were collected, and again about half a mile north of Ani Sakán, near the deserted village of Myenigôn (Loc. 40, **B** 5), where, in addition to *Tent. elegans*, a few specimens of a small *Lingula* were found. For some distance beyond this point no outcrop of the Zebingyi beds has been seen, but fragments derived from them, containing *Tent. elegans*, were picked up on the hill slopes between Letkaung and Lebyaungbyán, further to the north-east, and in a small landslip close to Naungkangyi village, near Maymyo; showing that the band continues along the edge of the Plateau Limestone in this direction, though its actual outcrop is concealed by rainwash.

Final appearance north of Maymyo.

The Zebingyi beds are concealed, either by faulting or by an overlap of the overlying Plateau Limestone, along the southern edge of the hills north of Maymyo, but they are found again at the very edge of these hills on their eastern side, in a small stream about a mile north of Taungmio (Loc. 45, **C** 4). Here *Tentaculites elegans* occurs in as great profusion as at Kyinganaing, and in a similar clayey rock, but the graptolites can hardly be detected.

This is the final appearance of these beds, at least so far as they can be identified by the presence of Tentaculites and Graptolites. Beds of black limestone shales occur to the north and east in a similar position, at the base of the Plateau Limestone, but careful search has failed to discover either of these fossils beyond this point.

Pangyu beds.

On the northern edge of the plateau extending eastwards from the hills just mentioned some black limestones which must be close to, if not quite at the base of the Plateau Limestone, and therefore on or about the horizon of the Zebingyi beds, occur in a depression, a little west of the village of Pangyu (Loc. 46, **C** 3), on the path to Namhsu-hká. The fossils collected here were:—*Atrypa marginalis*

Fossils.

Dalman, a species having a very wide distribution, occurring in the upper Ordovician of Britain and Scandinavia, and the Silurian of Central Europe and North America. The Pangyu specimen is well preserved, and only differs from the usual form in possessing fewer lateral ribs; *A.* (*Atrypina*) *subglobularis* Reed, a new species resembling *A. semiorbis* Barr. from Ét. F 2 (upper Ludlow), and

A. Cybele from Ét. E 2 (Wenlock) in Bohemia; *Meristina* sp., the same that, as we have seen, occurs at Zebingyi; *Dualina* (?) sp. a small lamellibranch possessing a considerable resemblance to *D. socialis* Barr. and *D. inflatula* Barr., both from Ét. E 2 (Wenlock) in Bohemia; and lastly a small species of *Lunulicardium*, resembling *L. amabile* Barr., from the same horizon in Bohemia. In America, and in Europe outside Bohemia, the genus is more common in the Devonian period. It will be noticed that none of the characteristic Zebingyi forms were found here, but the outcrop visible is exceedingly small, and it is quite possible that the Tentaculites beds would be found if a quarry were opened at this spot.

Range and distribution of species.

The relations of the Zebingyi fauna with its representatives in other countries are summarised in Table 6:—

TABLE 6.

List and Distribution of Zebingyi Fauna.

TABLE 6.

List and Distribution

NAME.	RANGE AND DISTRIBUTION OF GENERA.
HYDROZOA.	
Monograptus dubius Suess	Sil., Cosmopolitan . . .
,, riccartonensis Lapw.	Ditto . . . .
,, sp.	Ditto . . . .
BRACHIOPODA.	
Lingula (?) sp.	Ord.-Recent, Cosmopolitan .
Atrypa marginalis Dalman	Ord.-Dev., Cosmopolitan .
,, (Atrypina ?) **subglobularis** Reed .	Sil.-Dev., Europe, N. America .
Meristina(?) sp.	Sil., Europe, North America .
PELECYPODA.	
Modiolopsis **shanensis** Reed	Ord.-Sil., Europe, North America.
,, sp.	Ditto . . . .
Lunulicardium aff. amabile Barr. . . .	Sil.-Dev., Europe, North America.

NOTE.—For explanation of

of Zebingyi Fauna.

Nearest Allies.	Horizon and Distribution of Species or nearest Ally.				Remarks.
	N. Europe.	Great Britain.	Bohemia.	N. America.	
—	Lw.	Wk. L. Lw.	Lw.	..	
—	Wk.	Wk.	..	..	
—	..	..	..	..	
—	..	..	..	..	
—	Cc.-Wk.	Cc.-Wk.	Wk.	Wk.	
A. semiorbis Barr. .	..	..	Lw.	..	
A. cybele Barr. .. .	..	..	Wk.	..	
—	..	..	..	..	
M. simplicissima Barr.	..	..	Wk.	..	
Mytilus gradatus Salter.	..	..	Lw.	..	
—	..	..	..	..	
—	..	..	Wk.	..	

Abbreviations *see* Table 4.

TABLE 6—*contd.*

List and Distribution

NAME.	RANGE AND DISTRIBUTION OF GENERA.
PELECYPODA—*contd.*	
Dualina(?) sp.	Sil.-Dev., Europe
Vlasta (?) sp.	Sil., Bohemia
PTEROPODA.	
Tentaculites elegans Barr.	Sil.-Dev., Cosmopolitan
,, *cf.* ornatus Sow.	Ditto
Styliolina *cf.* lævis (?) Richter	L. Dev., Europe
CEPHALOPODA.	
Orthoceras aff. commutatum Giebel	Ord.-Trias, Cosmopolitan
,, aff. mocktreense (?) Sow.	Ditto
,, aff. nicholianum Blake	Ditto
,, sp.	Ditto
ARTHROPODA.	
Phacops (Dalmanites) Swinhoei Reed.	Ord.-Dev., Cosmopolitan

Zebingyi Fauna—*contd.*

Nearest Allies.	Horizon and Distribution of Species or nearest Ally. N. Europe	Great Britain.	Bohemia.	N. America.	Remarks.
{ *D. serialis* Barr. . .	..	..	Wk.	..	
{ *D. inflatula* Barr. .	..	..	Wk.	..	? L. Dev. Ural.
{ *V. tumescens* Barr. .	..	..	Wk.	..	
{ *V. bohemica* Barr. .	..	..	Wk.	..	
{ —	..	..	L. Dev.	..	
{ *T. acuarius* Richter .	..	..	..	..	L. Dev. Harz.
—	..	Wk.	..	Lw.	U. Sil., N. S. Wales.
—	..	..	..	..	L. Dev., Harz.
{ —	..	..	..	..	L. Dev., Harz.
{ *O. distans* Sow. . .	Cc.	L.-Lw.	..	..	
—	..	Lw.	..	..	
—	..	Ly.-Lw.	..		
—	..	..	..	..	
Ph. Hausmanni Brongn .	..	..	L. Dev.	..	

Classification.

I have treated this fauna as distinct from that of the underlying Silurian formations, both because it is evident, from a study of its affinities, as shown in this list, that it marks a new phase in the conditions prevailing in the Burmese region, and because some doubt exists as to whether these beds should not be classed rather with the overlying Plateau Limestone, which is certainly in part of Devonian age, than with the strata of Silurian age already described.

The reasons that have led me to place these beds in the Silurian system are, not only the occurrence in them of graptolites, the presence of which is looked upon, at least among English geologists, as a kind of 'hall mark' peculiar to that and older systems; but also a consideration of the general facies of the fauna they contain. The great majority of the species are certainly of Silurian,—Wenlock or Ludlow,—types; but the extraordinary profusion of the annelid *Tentaculites elegans*, a characteristic lower Devonian species, and the equally characteristic affinities of the few trilobites that accompany it, might lead some geologists to argue that in this region graptolites may have survived into Devonian times, and that the beds should be classified accordingly. The stratigraphical evidence is by no means in conflict with this view; on the contrary, there appears to be a perfectly gradual passage from the graptolite beds into the overlying limestones. The case seems to bear a very close resemblance to that of the relations of the Silurian and Devonian rocks in the classic area on the borders of Shropshire and Herefordshire; where we have a series of 'Passage beds' containing, on the one hand, graptolites, and, on the other, a euripterid and cephalaspid fauna, whose affinities lie rather with that of the overlying Old Red Sandstone. In that case the classification of the 'Passage beds' with the Silurian is generally accepted. For these reasons I prefer to adopt what I may call the 'graptolite convention,' for convenience of classification only; knowing that if I err in doing so, I err in good company. I therefore include the Zebingyi beds in the Silurian system.

As regards the affinities of the Zebingyi fauna, it has been shown that the fossils from the formations hitherto dealt with, the Naungkangyi and Namhsim groups, belong mainly to types characteristic of strata of similar age in Northern and Western Europe; but in the beds now under consideration the most important fossils possess a distinctly

Hercynian type.

Bohemian or Hercynian facies. Among all the fossils described from the lower groups there are only two that are of a distinctively Bohemian type, *viz.*, *Aristocystis* in the Ordovician and *Mimulus* in the Silurian; but in the Zebingyi beds we have, of 20 species described, 12 belonging to or closely allied with forms from Bohemia or the 'Hercynkalke' of the Harz; while of these **6** are peculiar to that province, including such distinctive forms as *Lunulicardium amabile*, *Dualina* (?) sp., *Vlasta* (?) sp., and *Tentaculites elegans*. The only characteristic Northern or Western European forms are *Monograptus riccartonensis*, *Atrypa marginalis*, a widely ranging species, *Tentaculites ornatus*, and the cephalopods *Orthoceras* aff. *mocktreense* and *O. nicholianum*, the identification of both of which is doubtful. Some considerable change in the distribution of land and sea must therefore have taken place in the interval between the deposition of the Námhsim series and that of the Zebingyi beds, but our information is as yet too scanty to enable us to do more than speculate regarding the nature of this change.

Migration of fauna.

Mr. Cowper Reed has discussed the question of the correlation of this fauna in his Memoir (*Op. cit.*, pp. 152-154), and points out that a Hercynian fauna has been described by Tschernyschew from the western slopes of the Urals. He remarks that—

"Frech has suggested that the birth-place of this fauna was situated in the east and south-east of Europe and that its migration proceeded in a westerly direction, so that it did not reach America till later Devonian times. It is open to us now to speculate whether the heralds of this fauna did not first appear in South-Eastern Asia before the Silurian period came to an end, and that thence it spread westwards into Europe."

But the Burmese evidence seems to me to point rather the other way, for we have a characteristic Wenlock graptolite, *Monograptus riccartonensis*, associated with and on the same slab of rock as the Devonian *Tentaculites elegans*; and a glance at the list will show that most of the other species are of Wenlock age in Europe, while some are even older.

No inversion of strata.

As I pointed out in a note published at the end of Mr. Reed's Memoir (page 154), there is no question of an inversion of the beds, such as he suggests might account for the presence of limestones with a Hercynian fauna below the graptolite shales. The occurrence

of the beds in the same relative order, with low dips corresponding to those of the Plateau Limestone above, on either side of the shallow Zebingyi syncline, is alone sufficient to disprove this theory, as well as the continuous passage upwards from the one formation into the other, which may be followed without any gap through the Zebingyi railway cuttings, and is also seen in the long line of outcrop reaching from Pyinthá to Myenigôn.

Connection with European provinces.

In any case the connection with the Urals does not appear to have been very direct, for only one of the peculiar forms of the Zebingyi beds, and that a doubtful genus and species, *Vlasta* sp., is allied to any of those described by Tschernyschew. If the Hercynian fauna had appeared in South-Eastern Asia before the end of the Silurian period, it is difficult to understand why more traces of it are not to be found in the Námhsim group. The only fossils belonging to that facies that occur in that group are *Mimulus aunglokensis* and *Phacops shanensis*, the latter of which has been found not only in the area where the graptolite shales are present, but also far to the south-east in Möng Küng. It appears to me more likely that there had been, throughout the Naungkangyi and Námhsim period, some connection between the seas of Burma and those of Southern Europe, but not so direct as that with the seas of Northern and Western Europe; so that the fauna of the latter province frustrated any attempt of the southern fauna to travel eastwards: but that with the changes in the distribution of sea and land that began to take place at the close of Silurian times a more direct connection with Southern Europe was opened up. The movements that effected this change may have only partly closed the old connection with Northern Europe, allowing the Hercynian fauna to travel on the one hand towards the Urals and on the other to the South-East without interference.[1]

Himalayan equivalents.

By what route the migration took place is quite uncertain. It was certainly not by way of the Himalayan region, for no traces of this fauna have been found there; but in Spiti and the Central Himalaya the homotaxial equivalent of this horizon is probably the 'Muth quartzite,' which succeeds strata of undoubted Silurian age, and comes beneath a limestone which, there is some reason to believe,

[1] F. R. Cowper Reed, Pre-Carboniferous Life-Provinces, *Records, Geol. Sur., Ind.*, Vol. XL, Pt. 1, p. 26.

is of middle Devonian age, since it contains *Orthothetes umbraculum* Schloth., *Atrypa aspera* Schloth., and *Cyathophyllum* sp.[1] The Muth quartzite has yielded no fossils, but it is by no means unlikely that fossiliferous beds corresponding to it in age may occur further to the north, in the little known districts north of the Tibetan Plateau, where traces of the Hercynian fauna have been found.[2]

First symptoms of Devonian transgression.

A submergence of the northern part of the barrier that I suppose to have existed during Ordovician and Silurian times between our area and the southern branch of the 'Tethys' may have opened up a connection with the northern portion of that sea. However that may be, it seems certain that we have, in the Hercynian fauna of the Zebingyi beds, the first indication in South-Eastern Asia of those great changes in the distribution of sea and land which, as we shall find later on, brought a true middle Devonian fauna into Burma, and culminated in a wide-spread transgression of the Permo-Carboniferous ocean over those tracts of Asia lying to the north of Gondwana-land.

[1] H. H. Hayden, Geology of Spiti; *Memoirs, Geol. Surv. Ind.*, Vol XXXVI, Pt. 1, p. 34.

[2] A. de Lapparent, Traité de Géologie, 5th Edn. p. 849.

CHAPTER IX.

PLATEAU LIMESTONE.

Devonian Section.

Nomenclature.

Although the formation now to be described extends beyond the limits of that part of the Shan States which may be strictly denominated a plateau, often forming rugged and precipitous hills (such as the Myaleit daung, which is so conspicuous a feature in the landscape to the south-east of Mandalay that it at once attracted the attention of the first geologist who visited that city, Dr. T. Oldham,[1] who ascended it in 1855): yet the name now given to it seems as appropriate as any that could be devised, for this limestone is not only the most widely prevailing rock that is to be found on the plateau of the Shan Hills, but it is to the peculiar constitution and mode of weathering of this rock that the distinctive characters of the upland plateaux are due. It is indeed remarkable how these characters are reproduced wherever a detached outlier of the limestones occurs among the older rocks, even if it be of small dimensions;—at Zebingyi for instance, where the toiling locomotive obtains a brief breathing space on the long ascent from the Irrawaddy plains to Maymyo;—and after some little experience the mere appearance of the ground will always indicate whether the rock below the surface belongs to this formation or not, even though not a single outcrop of solid rock may be visible through the thick mantle of red clay which usually conceals it. The prevailing type of scenery is somewhat monotonous, wide shallow valleys, separated by low swelling hills or ridges, succeeding each other, their outlines smoothed off by the universal covering of clay, except in the few places where a scarp, usually indicating the line of a fault, presents a succession of precipitous cliffs to the view, or where one of the numerous canyon-like gorges crosses the path of the traveller (Plates 2 and 10).

Plateau type of landscape.

Nature of soil.

These rolling uplands are as a rule not well cultivated, for the soil is of poor quality, and naturally supports little but coarse grasses and scattered oak trees, and where it has formerly been cleared for cultivation, a low scrubby jungle. it is only in the shallow valleys, where the soil is enriched by

[1] H. Yule, Mission to the Court of Ava in 1855, Appendix, p. 336.

deposits of calcareous silt, and where water is easily obtainable by a system of irrigation channels, that continuous cultivation can be carried on. Elsewhere, on the hill slopes, it is quickly impoverished, and the clearings will only produce crops for an average period of four years, after which they are allowed to lie fallow until the scrub has grown up again, when it is cut down and burnt, and the process is repeated. The water that falls on the slopes too is either run off at once by the stiff impervious clay, or sinks deep below the surface through fissures in the limestone. No systematic attempt is made to terrace these steeper hill slopes, though sometimes the soil is allowed to collect against a fallen log or a rock; but if this were done it would certainly retard the impoverishment of the soil for a much longer time. The addition of lime to the clay, which could easily be done by the cultivators if they were possessed of sufficient energy,—for limestone may be obtained everywhere,—would doubtless tend to its amelioration; for it is a curious fact that, though the red clay has been derived, to a great extent, if not entirely, from the disintegration of the limestone, analyses show that it contains no trace of lime. Among wild plants the common bracken fern, *Pteris aquilina*, is found universally over the limestone area, and is often of use in determining the limits of the formation when no outcrops are visible, though it is by no means confined to this area.

Distribution.

The Plateau Limestone is known to extend far to the south into the Southern Shan States and the Karen country, and is probably continuous with the limestones in which the well known guano caves of Moulmein are situated. To the south of Moulmein it continues through Tenasserim, but has hitherto been described only from isolated localities, since no connected survey of that country has yet been made. A small number of fossils was collected from these rocks in Tenasserim several years ago by Mr. P. N. Bose, and were described by Dr. Noetling,[1] who pronounced them to be of Carboniferous (probably upper Carboniferous) age.[2]

Fossils in Tenasserim.

[1] Carboniferous Fossils from Tenasserim; *Records, Geol. Surv. Ind.*, Vol. XXVI, Pt. 3, p. 96.

[2] Previous to this fossils had been found in Tenasserim by Dr. Oldham (*Sel. Records, Govt. of India*, No. X, p. 33), and by Mr. Theobald in the limestones near Moulmein (Geology of Pegu; *Memoirs, Geol. Surv. Ind.*, Vol. X, Pt. 2, p. 138). Both of these observers considered the fossils to be of Carboniferous ages but they were never described and are now lost.

Northern extension.

These limestones extend northwards on the eastern side of the Nám-Tu beyond the limits of the map, but how far is not yet known. Similar limestones have been found in Yunnan, and the expeditions of Richthofen, Loczy, and others have shown that rocks of the same age are spread over a wide area in China, but how far these correspond with their development in the Shan States cannot yet be determined. They also extend eastwards across the Salween river into Kengtung, probably as far as the Mekhong and the frontier of Siam, but nothing further is yet known of the geology of the Trans-Salween country. On the west the limestones come down for a short distance, opposite Mandalay, to the edge of the Irrawaddy alluvium, as the map shows; but to the north and south of this interval they are separated from the plains by a strip, of varying width, of crystalline Archæan rocks.

Eastern extension.

Western limits.

Former extent of formation.

Whether the Plateau Limestone once extended much beyond its present limits in the Northern Shan States, and has since been removed by denudation, it is difficult to say. Facing the Irrawaddy valley on the west, and along the line dividing the plateau from the hilly country of Tawngpeng to the north, the edge of the plateau is usually a precipitous scarp, evidently the result of long continued sub-aerial denudation, separated from the more rugged country beyond by a more or less broad valley, on the floor of which the rocks below are exposed. But no outlying masses of the limestone have been found resting on the older rocks beyond the valleys, and there is nothing to show that it ever extended further than the base of the hills. At other places, where no stream runs along the base of the older hills, as for instance on the flanks of Loi Ling and the Loi Pan - Loi Twang range, the undulating plateau continues uninterruptedly up to the very foot of the high ground, giving the impression of a group of mountainous islands rising from an encircling sea. But this appearance is to a certain extent deceptive, for in some instances, as in the Loi-len range, the limestones arch over the older formations, and in others a fringe composed of the formations lying between the Chaung-Magyi series and the Plateau Limestone intervenes, showing that the disturbances which led to the upheaval of the higher ranges to their present relative altitude took place since the deposition of the limestone. It seems, however, quite possible that, while the limestones were being

accumulated, the sea was studded with a number of islands occupying the same positions as the present ranges, though not of the same dimensions and altitude; for it has been observed that as we approach the base of any of these island-like masses, the limestone becomes sandy and in some cases passes into a calcareous sandstone, indicating the proximity of a coast. Abundant evidence also of the overlap of the lower beds of the limestone series by the higher is not wanting. On the other hand, no conglomerates have been found at the base of the limestone, wherever this is exposed, a circumstance that seems to indicate that the actual line of coast does not occupy the position of the present boundary, but lay further out on all sides. If this was the case, the absence of outliers is easily accounted for by the readiness with which limestones are attacked and removed by denuding agents.

Thickness.

The maximum thickness of this great mass of limestone is another point on which considerable doubt exists. In only two instances yet found within the plateau area has the limestone been cut away to a sufficient depth to expose the base of it and to allow its position with regard to the rocky floor beneath it to be seen. One of these is in the deep gorge of the Nám-Tu or Myitngé river at Lema (**C** 5), about 15 miles due south of Maymyo. Here the sides of the gorge are entirely composed, down to within 300 feet of the river, of the limestones, resting at Lema itself, so far as can be seen, on the upturned edges of the quartzites and shales of the Chaung-Magyi series, which are highly disturbed and in places vertical, and a little to the west upon almost equally highly inclined Naungkangyi beds. The limestones are only slightly disturbed and the thickness seen here is not less than 2,500 feet; but every vestige of overlying strata has been removed, and the original upper limit of the formation cannot be determined; while a considerable thickness must also have been denuded away from the top of the limestones. In any case, their original thickness here was probably not less than 3,000 feet.

Section at Lema.

Kyaukkyan scrap.

The other instance is at the southern end of the great scarp south of Kyaukkyan, where a fault has brought the underlying strata to the surface. Here also the limestones have suffered very greatly from denudation, and their original thickness cannot be measured. At the viaduct in the Gok-

teik gorge the base of the limestones is not visible, but at least 2,000 feet are exposed in the cliffs on the eastern side.

Nám-Tu valley.

A more complete section is exposed on the lett bank of the Nám-Tu to the north of Hsipaw, where the limestones occupy a band of about three miles in width between the crest of the scarp of Silurian rocks overhanging the river on the west and the red sandstones and shales of the Namyau series to the east. Thus both the base and top of the Plateau Limestones are well defined. The inclination of the whole sequence is fairly uniform, and may be taken as 25 degrees on the average. This would imply a thickness of about 6,600 feet for the limestones; but even here it is not certain that some portion of them was not removed before the deposition of the overlying strata, for banks of calcareous conglomerate filled with well rolled pebbles of the limestone have been observed at several places at or near the base of the Namyau beds, showing that some denudation had taken place in the interval.

Evidence of erosion.

Loi-len range.

The band of this limestone exposed on the northern flanks of the Loi-len range, where the red beds are also in position above it, is fairly uniform in width towards the western end of the range, and would measure about 5,500 feet in thickness, if we assume a dip of 45 degrees, which is rather under than over the average amount.

Lithological characters.

The prevailing type of the Plateau Limestone is a whitish or light grey rock, weathering to a darker grey and often stained red by iron oxide both on the surface and along the joint planes. It is often hard enough to strike fire with the hammer, and when struck usually gives out a more or less pronounced fetid odour, no doubt due to the presence of decomposed organic matter. In texture it is sandy to the touch and has a finely granular appearance, which at first gives one the impression that it is a siliceous limestone; but examination of thin sections under the microscope and chemical analyses show that the rock, except near its boundary with the older formations, where it occasionally passes into a sandy limestone, contains a very small proportion indeed of silica or argillaceous matter.

Chemical analyses.

From analyses made by the late Mr. T. R. Blyth, Assistant Curator, in the Geological Survey Laboratory, of a series of typical specimens of the limestone, it appears that they vary from an almost pure calcite, containing over 99 per cent. of that mineral, through dolomitic limestones, with from 19 to 33 per cent. of magnesium carbonate, to rocks containing the carbonates of lime and magnesia in the proportions of 55 to 44 per cent. respectively, or practically speaking, true dolomites. One point is to be noticed, however, namely, that the pure limestones belong to the Permo-Carboniferous horizon of the Plateau Limestones, and that all those from the massive, non-fossiliferous bulk of the formation yield an appreciable amount of carbonate of magnesia; also that those with the lower proportions of this substance contain a relatively large quantity of insoluble residue (*see* Table 7).

TABLE 7.

PLATEAU LIMESTONES.

Analyses and Specific Gravities.

No.	Reg. No.	Locality.	Calcium carbonate.	Magnesium carbonate.	Ferric oxide and alumina.	Insoluble residue.	Total.	Sp. Gr.	Remarks.
			%	%	%	%			
1	14,939	Ridge N. of Tonbo	99·39	·16	·79	·39	100·73	2·702	Permo-Carboniferous.
2	14,940	Ridge N. of Tonbo	99·46	·19	·39	·27	100·31	2·681	
3	17,814	Nampating	98·71	·91	·43	·91	100·96	2·688	
4	17/812	Ho-un stream	96·00	4·23	·35	·35	100·93	2·688	
5	17,816	Monghko	25·91	19·06	1·07	53·63	99·67	2·591	Sandy limestone.
6	15/900	Mandalay-Lashio cart road, mile 141.	62·06	28·85	·79	8·75	100·45	2·717	
7	15,903	Near Baw, S. of Maymyo	60·74	33·24	2·11	3·43	99·52	2·833	
8	17,819	Hill N. of Mongyaw	56·67	42·27	·87	·01	99·82	2·849	
9	14,893	Near Nawnghkio	55·49	42·54	·55	1·91	100·49	2·801	
10	14,977	Railway cutting below Zebingyi.	56·99	42·63	·49	·35	100·46	2·793	
11	14,957	Near Yebin	54·10	42·82	·63	1·87	99·42	2·841	
12	15/898	Hill W. of Mongyaw	56·28	43·62	·41	·01	100·32	..	
13	14,958	Near Yebin	55·55	44·45	·31	·07	100·68	2·841	

Origin of the dolomites.

A very significant fact brought out by these analyses is the comparatively small proportion of insoluble residue that they contain, except in those cases where the high percentage of foreign material is obviously due to the proximity, during the period of deposition, of argillaceous or siliceous rocks. Prof. Skeats has shown, in his researches into the composition and history of the coral-reef deposits of the South Seas,[1] that an almost inappreciable quantity of insoluble residue is a characteristic feature of limestones that have been formed under coral-reef conditions; and in applying the result of these researches to an enquiry into the origin of the dolomites of the Southern Tyrol,[2] he employs this characteristic as an argument in favour of the hypothesis that those rocks were formed under such conditions. In other respects also, in the manner in which dolomitisation has affected the rocks, in their composition and mode of occurrence, the Plateau Limestones resemble very closely, so far as one can judge by the descriptions published, the dolomites of the Tyrol, and I think that it is reasonable to ascribe to them a similar mode of origin.

Petrographic characters.

Thin sections of the specimens, the analyses of which are given in Table 7, as well as of a large number of other specimens, not analysed chemically, have been examined under the microscope. In all cases where more than 10 per cent. of magnesium carbonate was shown to be present by analysis the sections were also tested by Lemberg's solution, prepared according to the instructions given by Prof. Skeats in the first of his papers cited above,[3] but of only half the strength recommended by him; as it was found that, probably on account of the higher temperature prevailing in Calcutta, the action of the solution was very rapid, and it was difficult to avoid the deposition of a thick layer of alumina on the calcite, with consequent shrinkage on drying.

Lemberg's solution.

1 Chemical Composition of Limestones from upraised Coral Islands; *Bull. Mus. Comp. Zoology*, Vol. XLII, p. 103.

2 *Quart. Journ. Geol. Soc. London*, Vol. LXI, p. 97.

3 The formula of this solution, as given by Prof. Skeats, is as follows:—

Aluminium chloride, dry, 4 parts.

Water, 60 parts.

Dissolve, then add:—

Hæmatoxylin campechianum (Logwood), 6 parts.

Boil and stir for 25 minutes; filter, and make up to the same bulk with water.

Five minutes' immersion in the solution was generally found to be sufficient.

Typical dolomite.

Under the microscope thin sections of the ordinary massive limestones, such as the two specimens from near Yebin (**D** 3), Nos. 14/957 and 14/958, are seen to consist of a granular aggregate of minute dolomite crystals with irregular outlines, interlocking with each other (Plate 11, fig. 2). The individual crystals are usually clouded with brown semi-opaque matter, which is often concentrated in the centre, leaving a narrow clear zone round the edge. Where cavities are present the mineral filling them is clear, and frequently has a tendency, sometimes very pronounced, to crystallise in idiomorphic rhombohedra. Any calcite that the rock contains, as shown by staining with Lemberg's solution, is confined to fine cracks and veins, and is evidently of secondary origin. This is well seen in No. 14/958.

Calcite veins.

Dolomitic limestone.

In the specimen No. 15/903 from near Baw (**C** 5), to the south of Maymyo, the mass of the rock is of exactly the same character as at Yebin, but it is traversed by comparatively wide cracks filled with clear secondary calcite, which accounts for the lower percentage of magnesium carbonate in this rock.

Brecciated dolomites.

In other cases also the lower percentage of carbonate of magnesia is due to the brecciation of the original dolomite, and the re-cementing of the fragments *in situ* by a finely granular calcite paste. Staining with Lemberg's solution makes this very clear in No. 15/900, from near Kônghsâ bungalow on the Mandalay-Lashio cart road (**F** 2), where the fragments are not acted upon, but the cementing material is distinctly stained. The cracks in this rock are filled partly with clear crystalline dolomite and partly with calcite. This rock also contains minute grains of quartz, which account for the comparatively high percentage of insoluble matter. In another specimen from the same locality, No. 14/976, the original rock seems to have been traversed by fissures which were then filled with a mixture of calcite and dolomite, and afterwards crushed and re-cemented; for some of the clear fragments were evidently derived from veins, and consist partly of calcite and partly of dolomite. No. 14/977, from a cutting on the railway below Zebingyi, is also a brecciated rock, but in this case the cementing material is entirely dolomitic,

a very minute proportion of calcite only being present, as shown by staining, in the interstices.

Oolitic dolomites.

Foraminifera.

Nos. 15/898 and 17/819, from a low hill near Mongyaw (Lat. 23° 2′: Long. 98° 9′, *i.e.*, just beyond the northern limits of the map), on the road from Lashio to the Kunlôn Ferry, are oolitic dolomites, containing numerous specimens of minute foraminifera, among which a species of *Endothyra* is the most common, with a few of *Textularia* and perhaps *Trochammina*. The groundmass of the rock, which consists of a granular mosaic of cloudy dolomite crystals, the oolitic granules, and the organisms are all unaffected by Lemberg's solution, showing that no calcite is present as such in a visible form. In No. 15/898 (Plate 12, fig. 1) the oolite granules are circular or oval in shape, defined by a thin dark line, and freely distributed through the groundmass either singly or in pairs. The interior is lined by an aggregate of dolomite crystals, generally exhibiting idiomorphic outlines, of larger size and usually less cloudy than those forming the groundmass. These sometimes fill the whole of the granule, but in most cases either did not do so originally or have been dissolved or broken away, so that the rock is now filled with minute pores. The organisms lie in the groundmass outside the oolitic grains. No. 17/819, though also an oolitic dolomite, is of a different character (Plate 12, Fig. 2). In it the oolitic granules are coagulated together into large, semi-opaque, irregularly shaped patches, which appear to be crushed fragments of an original oolitic limestone, for they are cemented together by a fine-grained matrix of granular dolomite which seems to have grown outwards from the edges of the individual patches; for, wherever these are parallel to each other, the space between is occupied, first by a zone of fine-grained, cloudy dolomite, and then by larger, often idiomorphic crystals of clearer dolomite, filling up the centre of the space after the manner of a mineral vein. In some instances the zoned effect is very clear, the crystals more immediately in contact with the oolitic patches exhibiting a 'dog-tooth' arrangement, with the apices of the crystals pointing outwards. Most of these 'dog-tooth' crystals themselves are zoned with cloudy matter. (This structure is well seen in fig. 1, Plate 13). Single oolitic granules and foraminifera are freely scattered through the matrix. The structure of the granules is concentric, in alternate minutely crystalline and 'dirty' bends. In some cases the nucleus

Brecciated Oolites.

is dark, in others apparently crystalline, while in a few it appears to be a minute foraminifer. It is interesting to note that these organisms are the only ones that have escaped the general destruction of the shells of which the limestone must have originally been composed. This is in accordance with the observations of Dr. J. Murray and Mr. R. Irvine,[1] who showed that when the shells of marine organisms are subjected to disintegrating influences, those of the foraminifera are the last to disappear. No. 14/983, from the south side of the Gokteik gorge, near Nawnghkio (D 3), is also an oolitic limestone, but in this case the oolitic granules are more sparsely scattered through the rock, and consist of calcite, being stained with Lemberg's solution, while the groundmass of the rock is the usual granular aggregate of dolomite crystals (Plate 13, fig. 2).

Survival of Foraminifera.

The specific gravities of these rocks, so far as they have been determined, seem to form a rough, but fairly consistent guide to the proportion of magnesium carbonate that they contain; the specific gravity of pure dolomite being about 2·90, while that of calcite is about 2·70. Thus those specimens which have been shown by chemical analysis to contain over 40 per cent. of magnesium carbonate have specific gravities ranging from 2·793 to 2·849, as shown in Table 7. Intermediate varieties, with 25 to 33 per cent. $MgCO_3$, range from 2·717 to 2·833; and the pure limestones from the Permo-Carboniferous beds give specific gravities ranging from 2·68 to 2·70. A sufficiently large series of chemical analyses and accurate specific gravities has not yet been made to enable one to come to any definite conclusion on this connection, but I trust that one of my colleagues will be able to take in hand a detailed study of these limestones in the near future.

Specific Gravities.

The conclusions that we may legitimately draw from the enquiry so far as it has already gone, correspond very closely, I think, with those summarised by Prof. Skeats in his paper on the dolomites of the Southern Tyrol (*Op. cit.*, p. 138). They may be stated thus:—

Conclusions.

(1) The inappreciable amount of insoluble residue is in favour of the hypothesis that the limestones were formed under conditions similar to those of modern coral reefs.

[1] On Coral Reefs and other Carbonate of Lime Formations in Modern Seas: *Proc. Roy. Soc. Edinburgh*, Vol. XVII, p. 99.

(2) The mineralogical changes that the rocks have undergone are similar to those which have affected the limestones of modern coral reefs, *viz.*, the dolomitisation of the rock and the disappearance of the organisms that originally composed them.[1]

(3) The practically complete dolomitisation of the great mass of the Plateau Limestone is an indication that deposition took place in a slowly subsiding area, whereby sufficient time was allowed for the mineralising agents present in the sea water to have complete effect.

(4) Conversely, the fact that the Permo-Carboniferous band at the top of the formation has not been altered into dolomite is an indication, either of more rapid subsidence, or what is more likely, seeing that it is followed by a break in deposition, of a comparatively rapid upheaval above the surface of the sea.

(5) Some of the dolomite in the rocks is of a secondary character, and has been deposited directly from solution in fissures and cavities.

(6) The specific gravity of the limestone may perhaps be used as a rough guide in estimating the amount of dolomitisation that has taken place.

Pulverised structure of dolomites.

A very constant feature of the Plateau Limestone, and one which requires some description and explanation, is the extraordinary manner in which it has been crushed, to such an extent indeed that it is difficult to find a piece sufficiently large for a hand specimen that is not traversed in all directions by a network of veins or fissures filled with secondary calcite or dolomite; and when the filling of the veins has been leached out, the rock is in so pulverised a condition that a single blow with the hammer is often sufficient to reduce it to a heap of ballast or road-metal. These veins are frequently 'faulted' across by others, and 'slickensided' surfaces are not uncommon, indicating that differential movements have taken place in the mass, and that the movements have been spread over a period sufficiently long to allow one set of veins to be filled with solid material before the rock was again broken up and a fresh set formed. I do not refer here to the

[1] C. G. Cullis, The Atoll of Funafuti; Report, Coral Reef Committee *Roy, Soc. London*, 1904, Sect. XIV, p. 392.

bands of breccia re-cemented *in situ* that are sometimes met with; these appear to have been formed while the limestone was being deposited, and are probably of the nature of a 'reef-talus'; but to the general brecciation of the formation as a whole.

Causes of pulverisation.

There seem to me to be two possible explanations of this phenomenon. First, that the brecciation is due to the effect of an enormous stress, such as would be set up by the great earth movements that took place at the close of the Mesozoic period. That those movements had a profound effect upon the rocks of the whole area is shown by the violent folding that is exhibited by the sandstones and shales of the overlying Jurassic series (the Namyau beds), which are often vertical, and are usually inclined at high angles. On the other hand the Plateau Limestones are not, as a rule, thrown into steep folds, except among the Eastern Ranges, where they generally conform to the folding of the rocks beneath. Over the remainder of the area they are usually inclined at gentle angles, seldom exceeding 30 degrees, and are often horizontal; but here and there a narrow band may be found in which they are violently contorted. It appears that, where the limestone was of great thickness, that is to say, over what is now the plateau proper, it was compelled to yield to pressure, not by folding in the ordinary way, but by faulting and by a general crushing of the formation as a whole.

Settlement due to solution.

But there is another cause that may have produced this result, either by itself or by accentuating the effects of tectonic stresses, depending on the chemical composition of the rock itself. Ever since it was first formed, or at any rate since it was raised above the level of the sea, it has been exposed to the dissolving action of water containing carbonic acid in solution; and the amount of material that has been removed from the mass, judging by the enormous quantities that even at the present day are being carried off by the waters that percolate through the rocks and flow away in the rivers, must bear a very considerable proportion to its original bulk. The removal of this matter in solution results in a general settling down of the whole mass, more accentuated in those places where fissures allow a ready passage to the surface waters; and there is perhaps no more striking feature in the scenery of the Shan plateau than the enormous number of cup-shaped depressions, due to this cause, varying in width from mere

'sink-holes' of a few yards in diamete to broad valleys, severall miles in length, which may be found in most places, but chiefly along the crests of fault scarps or near the edges of the deep canyons in which the larger rivers flow (Plates 3, 4, and 5). The continual settlement caused by this constant removal of the substance of the rock does, I think, account satisfactorily for the universal brecciation observed, and at the same time for the evidence, given above, of a long continuance of the action; and it is, perhaps, the chief cause to which the general crushing of the limestone must be attributed.

Destruction of organic remains.

The recrystallisation of the limestone as dolomite, described above, is so universally developed, and has destroyed its original structure to such an extent, that it is exceedingly rare to find any trace of organic remains still left in it. As a general rule such organisms as do occur are confined to the upper part of the formation, which has not been converted into dolomite, and is much more compact and less coarsely crystallised than the lower; but where the alteration is complete an occasional ossicle of a crinoid stem, or the faintly visible 'dirt-band' outlining the septa or the circumference of what was once a coral are all that can be detected, with, in a few cases, some very minute foraminifera, only visible in thin sections under the microscope. Throughout the whole of the continuous expanse of limestone, extending from Maymyo to the Salween, with one notable exception, not a single determinable fossil that could be seen with the unaided eye has been found, though both my colleagues and I have examined thousands of outcrops with the most minute care. So meagre is the evidence of the existence of living organisms at this period, that one might be tempted to speculate on a possible precipitation of the limestone from the waters of an ocean saturated with carbonate of lime, if the fact that the remains of organisms can occasionally be detected did not at once prove that such a theory could not be maintained.

Homogeneity of formation.

This paucity of organic remains, together with the rarity of outcrops of more than a few square yards in area, the homogeneity of the whole formation, and the irregularity of the dislocations, whether folds or faults, that have affected the rocks, render any attempt to follow up definite horizons, or to establish any divisions within the formation, a hopeless task. And yet it bridges over a period of continuous deposition of very considerable length, *viz.*, that extending from

the close of the Silurian epoch, as shown by the graptolites of the Zebingyi beds, to the Productus and Fusulina limestones of Permo-Carboniferous age. It is extremely likely that, when the Southern Shan States come to be geologically surveyed in detail, it will be possible to separate off these upper limestones, which are of a different texture and composition from the pure micro-crystalline dolomites beneath, by a definite boundary line; but in the Northern States the upper limestones are so feebly developed, and their relations with the underlying rocks are so greatly concealed, that it is at present impossible to say where one ends and the other begins, or even whether they are conformable to one another or not.

Section at Tonbo.

At the western edge of the hills, near Tonbô (Loc. 27, **B** 5), where the rock in places is filled with specimens of *Fusulina elongata*, the compact and splintery rocks containing the fossils seem to pass imperceptibly, both horizontally and vertically, into the ordinary micro-crystalline dolomites, and I could find no definite line of division. I have therefore considered it advisable to include these upper fossiliferous rocks for the present with the rest of the formation.

Padaukpin Coral Reef.

The exception, referred to above, to the almost universal barrenness in organic remains of the lower part of this enormous mass of limestone, is of a truly remarkable character.

Middle Devonian fauna: Padaukpin.

At the close of the field-season of 1900-01 I had halted at Wetwin, a village about 12 miles east of Maymyo, in order to collect from some fossiliferous shales which I had discovered during the previous season, when the Myook, or native Magistrate of the place, brought me a handful of fossil brachiopoda, among which I recognised a well preserved specimen of *Atrypa reticularis*. On accompanying him to the spot where these fossils had been picked up, just outside the western gate of the neighbouring village of Padaukpin (Loc. 30, **C** 4), I found the surface of the ground strewn with fragments of limestone containing beautifully weathered out brachiopoda, corals, etc., and single specimens also imbedded in the surface clay. One of the first specimens that I picked up myself was an unmistakeable *Calceola sandalina*, which at once fixed the horizon of the bed within very narrow limits. The Myook then informed me that these fossils had long been known to the villagers and were in some

request by the Burmese as charms; and that in the time of King Mindoon Min, that is to say, about the middle of the last century, orders had been given to have excavations made at the spot, as it was thought that such an abundance of these strange objects indicated the presence of treasure of some kind hidden below; and traces of excavations were certainly still visible. On the first opportunity, I caused several cartloads of the surface soil to be carried down to a running stream near by and washed in baskets, when it became easy to pick out the fossils scattered through the washed gravel in the utmost profusion. I also had several pits opened in the solid rock, but although it could be seen that it was filled with fossils, it was only on the weathered surface, or in crevices to which air and water had penetrated, that they were suitable for collection.

Fossils.

In this manner a rich and varied assemblage of fossils was obtained, and the number of individual specimens in some cases was extraordinary, perfect examples of some species, *Cyrtina heteroclita* for instance, being washed out literally in hundreds. This collection was afterwards sent to Mr. Cowper Reed for description, and the results of his researches have been published in the *Palæontologia Indica*[1]; but before proceeding to an enumeration and discussion of the fauna, some description of the locality is necessary.

Situation of village.

The village of Padaukpin lies exactly a mile to the east by south from Wetwin railway station, and is therefore easily accessible from Maymyo, the summer head-quarters of the Government of Burma, while there is a good travellers' rest house at Wetwin itself, about two miles from the fossil locality. The surrounding country, up to the very gates of the village, is densely wooded, except along the valley of the Kelaung stream, flowing eastwards from Maymyo, which is covered with rice fields; and the people of the village are mainly engaged in the felling of timber. Immediately to the north of Wetwin station, and extending westwards along the railway, there is a precipitous limestone scarp, but this dies away rapidly to the east, and about Padaukpin the country is so featureless and the forest so dense that without a guide it is easy to lose one's bearings. In all this tract outcrops of solid rock are exceedingly rare,

[1] The Devonian Faunas of the Northern Shan States, *Pal. Ind.*, New Ser., Vol. II, Memoir No. 5.

except along the bed of the stream, where they are much concealed by thick deposits of calcareous tufa; and I have been unable, after the closest search, to identify the fossiliferous bed of Padaukpin anywhere else in the neighbourhood, or even to ascertain its position relative to the nearest outcrops. The portion of the bed exposed is about 50 yards in length, extending northwards from the west gate of the village, and a thickness of not more than 6 feet or so is visible. The rock has a gentle dip eastwards, which is that of all the outcrops seen in this direction for several miles, as far, in fact, as the base of the great scarp crossed by the railway at Kyauk-kyan.

Character of outcrop.

The fossils from this locality, described and figured by Mr. Cowper Reed, leave no room for doubt as to the age of the bed in which they are found. In an exhaustive summary of the results of his investigation of the collection Mr. Reed comes to the conclusion—

Age of Padaukpin reef.

"That there cannot be any hesitation in regarding the Padaukpin beds as homotaxial with the lower part of the middle Devonian or Calceola stage of Western Europe . . . for all the characteristic fossils of this stage (*Calceola sandalina, Cyrtina heteroclita, Orthothetes umbraculum*, etc.) are specially abundant and there are very few definitely recognised species which are only known from higher middle Devonian beds." (*Op. cit.*, p. 144.)

The following list (Table 8), shows the species that have been found at Padaukpin, with their distribution in other parts of Asia, North America, and Australia. In column 2 those species which are limited to, or are specially characteristic of, the uppermost zone of the Calceola stage in Western Europe are marked U, while the species enumerated in the third column do not occur in Europe below the upper part of the middle Devonian, or belong to higher horizons; new species are printed in heavier type.

List of fossils.

TABLE 8.

List and Distribution of Padaukpin Fauna.

TABLE 8.

List and Distribution of

PADAUKPIN.	WESTERN EUROPE. Calceola stage.	WESTERN EUROPE. Upper Middle Devonian or higher horizons.
ACTINOZOA.		
Cyathophyllum ceratites Goldf.	×	..
,, ,, var. marginatum	×	..
,, bathycalyx Frech.	×	..
,, cæspitosum Goldf., var. breviseptatum Frech.	..	..
,, helianthoides Goldf., var. spinulosum Reed.	..	..
,, cylindricum Schulz.	..	..
,, (?) dianthus Goldf.	..	×
,, birmanicum Reed.	..	..
,, cf. quadrigeminum Goldf.	..	..

Padaukpin Fauna.

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	×	..	..	..	..	..	
..	..	..	..	..	..	×	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	×	..	×	..	..	..	? ×	..	
..	..	..	..	..	..	..	..	×	..	? ×	..	cf. *C. helianthoides*, Up. Calceola stage.
..	..	..	..	..	..	..	..	×	..	..	..	
..	..	..	..	..	..	..	..	..	..	×	..	
..	..	..	..	..	..	..	..	..	..	..	..	aff. *C. aquisgranense* Frech. Up. Dev., Germany.
..	..	..	..	..	..	..	..	..	..	..	..	

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Actinozoa—*contd.*		
Cyathophyllum (Blothrophyllum) sp.	..	..
Endophyllum (?) acanthicum Frech.	U	..
Diphyphyllum symmetricum Frech.	..	×
Zaphrentis aff. cornicula Lesueur.	..	..
,, sp. ind.	..	..
Amplexus hercynicus Roem.	..	×
Hallia quadripartita Frech.	..	×
,, (?) striata Schlüter.	×	..
,, (?) callosa Ludwig.	U	..
Aulacophyllum looghiense Schlüter.	×	..
Cystiphyllum cristatum Frech.	×	..
,, vesiculosum Goldf.	×	..

Padaukpin Fauna—*continued.*

ASIA.												
WESTERN.				CENTRAL.			EASTERN.					REMARKS.
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. AMERICA.	AUSTRALIA.	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *B. giganteum* Lesueur, Mid. Dev.
..	..	..	..	×	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	×	..	Onondaga Limest.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Z. incurva* Schlüter, Mid. Dev.
..	..	..	..	..	..	×	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..		..	..	..	..	..	..	..	..	..	..	
×	..	..	..	..	..	..	..	..	..	..	..	
×	..	..	..	×	..	..	..	..	..	×	..	

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Actinozoa—*contd.*		
Cystiphyllum (?) cæspitosum Schlüter.	×	..
Microplasma fractum Schlüter.	U	..
Calceola sandalina Lam.	×	..
Favosites Goldfussi D'Orb., var. major Frech.	×	..
Pachypora reticulata deBlainv.	U	..
Pachypora polymorpha Goldf.	U	..
Alveolites suborbicularis Lam.	×	..
„ ramosa A. Roemer.	×	..
„ **subplanata** Reed.	..	..
„ aff. expatiata Rom.	..	..

Padaukpin Fauna—*continued.*

ASIA.														
Western.				Central.			Eastern.			N. America.	Australia.	Remarks.
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	×	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
×	..	..	..	..	×	..	×	×	..	×	×	
..	..	..	..	×	×	×	×	×	..	×	×	
..	..	..	..	..	..	..	..	..	..	×	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	×	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Cladopora palmata* and *Cl. magna* Hall and Whitf., Chemung beds, N. America.
..	..	..	..	..	..	..	..	..	..	×	..	aff. *Cladopora expatiata.*

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Actinozoa—*contd.*		
Alveolites **illusa** Reed.	..	..
„ (?) (?) clathrata Stein.	×	..
Cœnites escharoides Stein.	×	..
„ expansa Frech.	..	×
(?) Striatopora (?) vermicularis McCoy.	×	..
„ cf. angulosa Gürich.	..	..
Trachypora Davidsoni M. Edw. and H.	..	..
Raphidopora crinalis Schlüter, var. aculeata Nich. and Foord.	×	..
Aulopora serpens Goldf.	×	..
„ cf. tenuis Münst.	..	..

Padaukpin Fauna—*continued.*

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	aff. *Al. subequalis* M. Edw. and H.
..	..	..	..	..	..	..	×	..	..	..	..	
..	..	..	..	..	..	×	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	? ×	..	..	..	..	..	aff. *Str. linneana* Bill., Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	Devonian, France, cf. *T. ornata* Rom., N. America.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	? ×	..	×	..	×	..	×	×	
..	..	..	..	..	..	..	..	..	..	..	..	Germany, Dev.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Actinozoa—*concld.*		
Aulopora **subcampanulata** Reed	..	..
Cladochonus aff. Schlüteri Holz.	..	×
Aulocystis cornigera Schülter.	×	..
Romingeria (?) sp.	..	..
Heliolites interstinctus Linné.	..	..
Hydrozoa.		
Stromatoporella (?) curiosa Barg.	..	..

Padaukpin Fauna—*continued.*

ASIA.												
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. America.	Australia.	Remarks.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *A. campanulata* McCoy, Carb. Limest; *A. conferta* Winch., Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	×	..	Typically Silurian.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev. England; aff. *Str.* (*Cœnostroma*) *incrustans* Hall and Whitf., Dev. of Iowa.

TABLE 8—*continued.*

List and Distribution of

PADAUKPIN.	WESTERN EUROPE.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
HYDROZOA—*concld.*		
Stromatoporella (?) eifeliensis Nich.	U	..
„ cf. granulata Nich.	..	..
„ sp.	..	..
Actinostroma clathratum Nich.	..	×
„ sp.	..	..
CRINOIDEA.		
Storthingocrinus fritillus Wirtz. and Zeiler	..	×
Cupressocrinus (?) Schlotheimi Stein.	..	..
„ cf. crassus Goldf.	..	..
Bactrocrinus birmanicus Reed	..	..

Padaukpin Fauna—*continued.*

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
×	..	..	..	..	..	..	..	..	..	..	×	
..	..	..	..	..	..	..	..	..	..	×	..	Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Str. laminata* Barg.
..	..	..	..	..	×	×	..	..	..	..	×	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *A. verrucosum* Goldf., Mid. Dev.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire, Eifel.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Eifel.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *B. fusiformis* F. Roem., Mid. Dve., Eifel.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Crinoidea—*contd.*		
Hexacrinus aff. pyriformis Schultze	..	..
,, aff. elongatus Goldf.	..	..
,, cf. spinosus Goldf.	..	..
,, sp.	..	..
Taxocrinus sp.	..	..
(?) Lophocrinus sp.	.	..
Lecythocrinus sp.	..	..
(?) Bactrocrinus sp.	..	..

Padaukpin Fauna—*continued.*

ASIA.													
Western.			Central.				Eastern.						
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. America.	Australia.	Remarks.	
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Gerolstein.	
..	..	..	..	..	..	..	..	..	..	..	..		
..	..	..	..	..	..	..	..	..	..	..	..	Dev., Eifel.	
..	..	..	..	..	..	..	..	..	..	..	..		
..	..	..	..	..	..	..	..	..	..	..	..	cf. *T. gracilis* Schultze.	Isolated stems and ossicles.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *L. minutus* F. Roem.	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *L. eifeliensis* Müll.	
..	..	..	..	..	..	..	..	..	..	..	..		

TABLE 8—*continued.*

List and Distribution of

PADUAKPIN.	WESTERN EUROPE.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
VERMES.		
Spriorbis omphalodes Goldf.	×	..
Ortonia cf. devonica Pacht.	..	..
BRYOZOA.		
Fistulipora quærenda Reed.	..	..
„ tempestiva Reed.	..	..
„ cunctata Reed.	..	..
„ memor Reed.	..	..
„ cf. vesiculata Hall.	..	..
„ aff. favosa Goldf.	..	..

Padaukpin Fauna—*continued.*

ASIA.										N. AMERICA.	AUSTRALIA.	REMARKS.
WESTERN.				CENTRAL.			EASTERN.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	×	..	..	..	×	..	×	×	..	×	
..	..	..	..	..	..	×	..	×	×	..	..	?=*Cornulites epithonia* Golfd., Dev., China.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Lichenalia colliculata* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf *Lichenalia vesiculata* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Pinacotrypa serrulata* Hall.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	×	..	Hamilton Group.
×	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Rhine.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Bryozoa—*contd.*		
Fistulipora (? Fistuliporella) **deterrens** Reed.	..	..
Eridopora **multidecorata** Reed.	..	..
,, sp.	..	..
Selenopora cœlebs Reed.	..	..
Buskopora **semilunata** Reed.	..	..
Hederella cf. magna Hall.	..	..
Fenestella arthritica Phill.	..	..

Padaukpin Fauna—*continued.*

ASIA.												
Western.				Central.			Eastern.			N. America.	Australia.	Remarks.
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	aff. *F. constricta* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *E. denticulata* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *E. ovata* Hall, *E. geometrica* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *S. circincta* Hall, Up. Helderberg Group.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *B. lunata* Hall, Up. Helderberg Group.
..	..	..	..	..	..	..	..	..	..	×	..	Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Bryozoa—*contd.*		
Fenestella aff. polyporata Phill.	..	..
Fenestrapora **isolata** Reed.	..	..
Hemitrypa oculata Phill.	..	..
,, **inversa** Reed.	..	..
Unitrypa sp.	..	..
Polypora populata Whidb.	..	..
,, **birmanica** Reed	..	..
,, **ultimata** Reed	..	..

Padaukpin Fauna—*continued.*

ASIA.												
Western.				Central.			Eastern.			N. America.	Australia.	Remarks.
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *F. occidentalis* Ulrich, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *H. columellata* Hall, Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *P. lævinodata. P. striatopora* Hall, Up. Helderberg Group.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *P. hexagonalis* Hall, Up. Helderberg Group.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Bryozoa—*concld.*		
Polypora (Reteporidra) sp.	..	..
Ptilopora sp.	..	..
Streblotrypa sp.	..	..
(?) Heterotrypa sp.	..	..
Brachiopoda.		
Stropheodonta interstrialis Phill., var. **birmanica** Reed	..	..
„ subtetragona F. Roemer. var. **padaukpinensis** Reed.	×	..

Padaukpin Fauna—*continued.*

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	.	..	..	..	..	aff. *P. adnata* Hall, Up. Helderberg Group.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *S. scutulata* Hall, Hamilton Group.
..	..	..	..	..	..	..	.	..	..	..	..	
..	..	..	..	..	..	..		..	..	..	..	*S. interstrialis*, Lower and Mid. Dev., Europe; aff. *S. concava* Hall, Hamilton Group; *S. hercynica* Barrois, Lr. Dev., N. France.
..	..	..	..	..	..	..	..	..	..	..	..	*S. subtetragona*, Calceola St., Eifel.

TABLE 8—*continued*.

List and Distribution of

PADAUKPIN.	WESTERN EUROPE.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
BRACHIOPODA—*contd.*		
Stropheodonta (Leptostrophia) palma Kayser	×	..
Strophonella caudata Schnur.	U	..
Leptæna rhomboidalis Wilckens.	×	..
Orthothetes umbraculum Schloth.	×	..
Kayserella (?) lepida Schnur.	U	..
Chonetes minuta Goldf.	×	..
,, sarcinulata Schloth.	×	..
Orthis (Schizophoria) striatula Schloth.	×	..
,, (? Schizophoria) sp.	..	..
,, (Rhipidonella) eifeliensis de Vern.	×	..
Scenidium arcola Quenst.	..	×

Padaukpin Fauna—*continued.*

ASIA.												
WESTERN.				CENTRAL.			EASTERN.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. AMERICA.	AUSTRALIA.	REMARKS.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
×	..	..	..	..	..	..	..	×	..	×	×	Cosmopolitan, Sil-Carb.
..	×	..	×	..	..	..	..	×	..	×	×	Occurs in Spiti Cent. Himalaya.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	×	×	×	..	..	×	..	×	..	×	×	
..	..	..	..	..	..	..	..	..	..	..	..	aff. *O. striatula.*
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe. Calceola stage.	Western Europe. Upper Middle Devonian or higher horizons.
Brachiopoda—*contd.*		
Pentamerus (Gypidula) brevirostris Phill.	×	..
,, (,,) biplicatus Schnur.	U	..
Camarophoria lummatoniensis Dav.	..	..
,, cf. brachyptycta Schnur.	..	..
,, cf. ascendens Stein.	×	..
Rhynchonella (Hypothyris) cuboides Sow.	U	..
,, (,,) var. (?) lungtungpiensis Kayser	..	..
,, (,,) pentagona Goldf.	..	×
,, (,,) Schnuri de Vern.	..	×
,, (,,) Schnuri var. transversa Reed	..	..

Padaukpin Fauna—*continued.*

ASIA.												
Western.				Central.			Eastern.					Remarks.
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. America.	Australia.	
×	..	..	..	..	..	..	×	×	..	..	×	aff. *P. galeatus.*
..	..	..	..	..	..	×	..	..	..	..	..	
..	..	..	×	..	..	..	..	?×	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Eifel.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	×	..	×	..	
..	..	..	..	..	..	..	..	?×	..	..	..	cf. *Rh. procuboides*, Dev., Urals
..	..	..	..	..	..	..	..	?×	..	..	..	cf. *Rh. dubia*, Urals.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	.	..	..	..	..	..	..	..	..	..	

TABLE 8—*continued*.

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Brachiopoda—*contd.*		
Rhynchonella (?Camarotœchia) **subsignata** Reed.	..	..
„ („) **subsignata** var.	..	..
Atrypa reticularis Lam.	×	..
„ (?) var. desquamata Sow.	×	..
„ aspera Schloth. var. sinensis Kayser.	..	..
Glassia Whidbornei Dav.	..	..
Spirifer **padaukpinensis** Reed.	..	..
„ **padaukpinensis** var. **dagon** Reed.	..	..

Padaukpin Fauna—*continued.*

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	aff. *Rh. Wahlenbergi* var. *signata* Schnur Mid. Dev., Eifel.
..	..	..	..	..	..	..	..	? ×	..	..	..	aff. *Rh. Omaliusi*, Upper Dev., N. France.
×	×	..	..	×	..	×	..	..	..	×	×	Cosmopolitan, Sil.-Dev.
..	..	..	..	×	..	×	..	×	..	..	×	
×	..	×	..	×	..	..	..	×	..	×	×	*A. aspera* occurs in Spiti, Cent. Himalaya.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	

TABLE 8—*continued.*

List and Distribution of

PADAUKPIN.	WESTERN EUROPE.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
BRACHIOPODA—*contd.*		
Spirifer (Reticularia) curvatus Schloth.	×	..
„ („) aviceps Kayser.	U	..
„ (Martinia) inflatus Schnur.	×	..
„ cf. Batschati v. Peetz.	..	..
Cyrtina heteroclita Defr.	U	..
„ „ var. multiplicata Dav.	..	..
„ sp.	..	..
Athyris concentrica v. Buch.	×	.
Nucleospira lens Schnur.	×	..

Padaukpin Fauna—*continued.*

ASIA.												REMARKS.
WESTERN.				CENTRAL.			EASTERN.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. AMERICA.	AUSTRALIA.	
..	..	..	..	..	..	..	..	×	..	..	×	
..	..	..	..	..	..	..	..	..	..	..	..	
..	×	..	..	..	..	×	..	×	..	..	..	prob. = *Nucleospira takwanensis* Kayser, Dev., China.
..	..	..	..	..	..	×	..	..	..	..	..	
×	..	..	..	..	..	×	..	×	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	
..	×	×	×	..	..	×	..	×	..	? ×	..	prob. = *A. spiriferoides* Eaton, Dev., America.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *N. concinna* Hall, Hamilton Group.

TABLE 8—*continued.*

List and Distribution of

PADAUKPIN.	WESTERN EUROPE. Calceola stage.	WESTERN EUROPE. Upper Middle Devonian or higher horizons.
BRACHIOPODA—*concld.*		
Ptychospira longirostris Kayser, var.	U	..
Merista (Dicamara) plebeia Sow.	×	..
Meristella cf. Haskinsi Hall.	..	..
(?) ,, **subdidyma** Reed	..	..
,, cf. upsilon Barr.	..	..
(?) ,, **subservata** Reed	..	..
,, aff. lacryma Sow.	..	.
(?) ,, sp.	..	..
PELECYPODA.		
Avicula sp.	..	..

Padaukpin Fauna—*continued.*

ASIA.												Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. America.	Australia.	
..	..	..	..	..	..	..	..	..	..	..	..	
×	..	..	..	..	..	..	..	×	..	..	..	
..	..	..	..	..	..	..	..	..	..	×	..	Hamilton Group.
..	..	..	..	..	..	..	..	..	..	..	..	aff. *M. didyma* Dalman, ?Dev., Urals.
..	..	..	..	..	..	..	..	..	..	..	..	Dev., Geissen. Occurs in Altai Mts.
..	..	..	..	..	..	..	..	..	..	..	..	cf *Atrypa serva* Barr.
..	..	..	..	..	..	..	..	..	..	..	..	Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	

TABLE 8—*continued.*

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Pelecypoda—*contd.*		
Conocardium rhenanum Bensh. var.	? ×	..
,, aff. eifeliense Bensh.	..	..
Paracyclas proavia Goldf.	×	..
,, rugosa Goldf.	×	..
Gastropoda.		
Platyceras compressum Roem.	×	..
,, orientale Reed	..	..
Loxonema aff. rugiferum Phill.	..	..
,, cf. funatum Roem.	..	..
,, sp. (*a*)	..	..
,, (or Holopella) sp. (*b*)	..	..

Padaukpin Fauna—*continued.*

ASIA.												Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. America.	Australia.	
..	..	..	..	..	..	..	..	..	..	..	..	Lr. Dev., Rhine.
..	..	..	..	..	..	..	..	..	..	..	..	
×	..	..	..	..	..	..	..	..	..	..	..	
..	×	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *Pl. trigonum* Roem.
..	..	..	..	..	..	..	..	..	..	..	..	Dev.-Carb.
..	..	..	..	..	..	..	..	..	..	..	..	Lr. Dev., Harz.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	cf. *H. Sandbergeri* Holz., Up. Mid. Dev., Rhine.

Table 8—*continued*.

List and Distribution of

Padaukpin.	Western Europe.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
Gastropoda—*contd.*		
Pleurotomaria (Euomphalopterus) cf. subulata de Vern.	..	..
,, sp. (*a*)	..	..
,, sp. (*b*)	..	..
Murchisonia sp.	..	..
Euomphalus radiatus Goldf.	×	..
,, Wahlenbergi Goldf.	..	×
Bellerophon lineatus Goldf.	×	..
(?) Macrochilina sp.	..	..
Dentalium sp.	..	..

Padaukpin Fauna—*continued.*

ASIA.										N. America.	Australia.	Remarks.
Western.				Central.			Eastern.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.			
..	..	..	..	..	..	..	..	..	..	..	..	Lr. Dev., France.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	aff. *M. bilineata* Sandb. Dev., Rhine; *M. loxomenoides* Whidb., Mid. Dev., Devonshire.
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	aff. *M. arculata* Schloth., Up. Mid. Dev.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *D. Saturni*, Goldf., Mid. Dev., Eifel.

TABLE 8—*concluded.*

List and Distribution of

PADAUKPIN.	WESTERN EUROPE.	
	Calceola stage.	Upper Middle Devonian or higher horizons.
CEPHALOPODA.		
Orthoceras aff. laterale Phill.	..	..
„ sp.	..	..
Anarcestes cf. lateseptatus Beyrich.	×	..
Agoniatites sp.	..	..
ARTHROPODA.		
Phacops latifrons Bronn. var.	×	..
„ (Dalmanites) cf. stellifer Burm.	..	..
„ („) punctatus Stein.	U	..

Padaukpin Fauna—*concluded*.

ASIA.												
WESTERN				CENTRAL.			EASTERN.					
Armenia.	N. Persia.	Hindu Kush.	Turkestan.	Tian Shan.	Kuen Lun.	Siberia.	Se Tchouan.	Yunnan.	Kwang-si.	N. AMERICA.	AUSTRALIA.	REMARKS.
..	..	..	..	..	..	..	..	..	..	..	..	Dev., Cornwall.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *O. venustum* Münst.
..	..	..	.	..	..	..	..	..	..	..	..	Occurs in the Altai Mts.
..	..	..	..	..	..	..	..	..	..	..	..	cf. *A. inconstans* Phill., var. *costulatus* D'Arch., Dev., Cornwall.
..	?×	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	..	..	..	

Affinities of fauna.

Mr. Cowper Reed has already discussed the composition and zoogeographical elements of this fauna at page 154 *et seq.*, of his Memoir, and I have little to add to his remarks. He calls attention to the predominance of European types, no less than 56 species from the Calceola stage of Western Europe being represented out of a total of 166, while 62 other species are either identical with, or closely allied to, species occurring in the Devonian of Europe at other horizons. Only twelve of these are enumerated by Mr. Reed as not found below the upper part of the middle Devonian or belonging to higher horizons. On the other hand, the American element is represented mainly by allied forms, and the resemblance is most close among the Bryozoa, certain of the Padaukpin genera (*e.g.*, *Selenopora* and *Buskopora*) not having been previously detected outside the American continent.

Organisms preserved at Padaukpin.

Too much stress, however, must not be laid upon the affinities or the composition of the fauna discovered at this single locality in discussing the distribution of invertebrate life at this period. It should be remembered that the Padaukpin fauna has only been found at one spot, covering an area of perhaps 100 square yards, and that it may throw little light upon the nature of the organisms that produced the bulk of the enormous mass of limestone that extends over the Shan States. I have already pointed out, as Mr. Cowper Reed remarks (*Op. cit.*, p. 154), that those organisms of which the casts only have been found at Padaukpin, such as the mollusca, are those in which the original shell was composed, either partly or wholly, of aragonite. Several observers[1] have shown that the absence of the remains of certain classes of organisms from limestones may be explained by the difference in stability between calcite and aragonite; and it seems possible that the predominating forms of life which produced the great bulk of the Plateau Limestone were mollusca, and that the Padaukpin fauna, rich as it is, gives a very incorrect picture of the life of the period in the Burmese region.

Instability of aragonite.

Remains of mollusca.

In the railway cuttings through the limestone on the zig-zags above Sedaw the remains of

[1] Gustav Rose, Über die heteromorphen Zustände der kohlensauren Kalkerde; *Abhandl K. Preuss. Akad. Berlin*, 1858, p. 63: H. C. Sorby, Presidential Address, *Geol. Soc. Lond.*, 1878: V. Cornish and P. F. Kendall, on the Mineralogical Constitution of Calcareous Organisms; *Geol. Mag.*, Dec. 3, Vol. V, p. 66.

mollusca,—gastropods and bivalves,—may be frequently seen in section on the face of the rocks, and though they are entirely converted into crystalline calcite, merely their outlines being left, they show that these forms of life must have been much more abundant than one would be led to suppose from a study of the Padaukpin fauna alone.

Significance of fauna.

This consideration does not of course detract in any way from the significance of the fact that we have here a fauna as closely resembling that of the Eifel as does that of the middle Devonian of Devonshire, although Padaukpin is separated from the former by an interval of 90 degrees of longitude and 35 of latitude.

Horizon of Padaukpin fauna.

Nothing is yet known regarding the position of the Padaukpin bed in the great mass of limestone that surrounds it. The base of the Plateau Limestone is not exposed for a distance of many miles in any direction, and the dips are so irregular and the existence of concealed faults so probable that it is impossible to say what horizon the reef occupies. The nearest fossiliferous beds are the shales of Wetwin, now to be described, and the fauna of these is so entirely different that it gives us no clue to the solution of the problem. It might be solved if a similar bed were found in any of the fault scarps, or on the sides of the gorges that penetrate the plateau, but though my interpreter, who was greatly interested in the fossils, and carried off several of those found at Padaukpin for the edification of his Burmese friends, made many enquiries from the natives, who are very keen prospectors, and though I have searched many a scarp myself, we never succeeded in discovering distinct traces of similar fossils at any other locality. Near the foot of the great Kyaukkyan scarp, on the descent from Enghpo to Hkelawng, 11 miles east of Padaukpin, I did indeed pick up, from the talus, a single specimen of the cast of a large gastropod, not unlike one of those found at Padaukpin, but quite unfit for determination. Unfortunately this happened before I had made the discovery at Padaukpin, and I was never able to revisit the locality. But it would be worth while to make a careful search along the scarp here; for if the bed from which this fossil came were found *in situ*, it might be possible to ascertain its horizon, seeing that a fairly complete section is exposed, from the Naungkangyis below to

Possible representatives in Kyaukkyan scarp.

the lower part of the Plateau Limestone, though much obscured by talus. A few very poorly preserved corals were also found near the western edge of the plateau, south of Nyaungbaw (Loc. 28, **B** 5), but though recognisable as *Cyathophyllum* or *Zaphrentis*, they cannot be identified with any of those from Padaukpin.

Fossils obtained from a single horizon.

Mr. Cowper Reed has remarked (*Op. cit.*, p. 145) on the apparent intermingling of species from different zones at Padaukpin, and has suggested in correspondence that some of the fossils in the collection may have been derived from other zones in the neighbourhood. I do not think that this is possible, even though many of the fossils were not actually extracted from the rock in position. The exposure at Padaukpin is situated near the summit of a gentle rise, on which the village is built, and there is no higher ground in the immediate vicinity from which some of the fossils might have been washed down. It is possible that we have here an example of the concentration of more than one zone within a small thickness of strata, owing to deficiency in sedimentation, as in the case of the Tropites Limestone described by Dr. C. Diener in Byans,[1] where a bed of limestone only 5 feet in thickness represents the carnic and noric stages of the Trias; but until the Padaukpin deposit has been opened out and thoroughly searched this point cannot be definitely settled.

Equivalents in China.

Yunnan.

The Devonian strata of China do not appear to attain any great thickness, and consist for the most part of dark bituminous limestones and shales. In southern Yunnan fossils of middle Devonian age were obtained by v. Loczy[2] from these beds; and in northern Yunnan a rich collection was made by v. Richthofen and described by Kayser.[3] These collections consist mainly of brachiopods, as shown in the foregoing list, and there is certainly a close resemblance in facies with this section of the Padaukpin fauna. In Central China the Devonian is represented, according to Bailey Willis,[4]—

Central China.

"throughout northern Ssi-ch'uan and southern Shen-si by thin strata of calcareous, marly, bituminous character, which nowhere attain very great

[1] Fauna of the Tropites Limestone of Byans; *Pal. Ind.*, Ser. XV, Vol. V, Mem. No. 1, p. 200.

[2] Reise des Grafen Bela Szechenyi, Vol. I, p. 682.

[3] Von Richthofen, China, Vol. IV, p. 75.

[4] Research in China, Vol. II, p. 59.

thickness, which may be in fact wanting in some sections, and which are conformable to the Silurian (Gothlandian) below and the Carboniferous above."

Transgression northwards.

The bituminous and shaly character of the Devonian strata in Yunnan and Central China, in contrast with the pure limestones and dolomites of the Shan States and the Malay Peninsula, suggests that the sea of that period was more shallow and less open towards the north and north-east, and that, as time progressed, the submergence that resulted in the accumulation of the massive Plateau Limestones in the southern portion of the ocean advanced northwards; for the Devonian beds of China are followed by a great thickness of limestones which, at any rate in Yunnan, resemble very closely the Plateau Limestone of the Shan States. This suggestion is in accordance with the statement of Bailey Willis (*Op. cit.*, p. 67) that the Carboniferous overlaps the Devonian, and in north-eastern China rests upon the Ordovician; and that it is towards the south and south-east, in Shen-si, Ssich'uan, etc., that the Carboniferous is represented by a great thickness, over 4,000 feet in places, of limestone; whereas the strata of the same age in Shan-tung and Shan-si consist of continental deposits of sandstones and shales, with beds of coal and occasional thin bituminous limestones (*Op. cit.*, p. 72).[1]

Wetwin Shales.

Situation and character of deposit.

The village of Wetwin is situated at the base of the precipitous scarp already mentioned, which the railway descends at about 12 miles east of Maymyo, and is built upon a band of shales which may be seen in all the watercourses flowing from the scarp, and in the cuttings along the surrounding roads and lanes (Loc. 29, C 4). These shales somewhat resemble a hard and fissile 'Fuller's earth,' and are very argillaceous, generally of a yellowish buff colour, mottled with pink or dark grey to black stains, of a type that is very common at various stages in each of the formations that occurs in the Shan States. They have been traced from the west side of the village, where the

Extent.

[1] The Devonian faunas as yet described from the Himalayan area are too scanty to permit the statement of any definite conclusions regarding a possible connection between that area and Burma (W. H. Hudleston, Devonian fossils from Chitral; *Geol. Mag.*, Dec. IV, Vol. IX, pp. 3, 49: F. R. Cowper Reed, Devonian fossils from Chitral, etc.; *Records, Geol. Surv. Ind.*, Vol. XLI, Pt. 2, page 86).

outcrop is much concealed by jungle and rainwash, along the Government cart-road and the lanes leading towards Padaukpin, for a distance of over a mile; that is to say, to within half a mile of the Calceola beds at the latter place; but a shallow ravine then crosses the line of strike, and is so choked with vegetation that the relations of the one deposit to the other cannot be made out. The beds dip gently to the north, towards the base of the scarp, and are evidently faulted against it. Their true horizon would therefore probably lie somewhere above the limestone which forms this scarp. In the direction of Padaukpin they show some indications of an easterly dip, as if they might, if continued, underlie the Calceola beds, but it is not by any means certain that a fault does not occur in the interval between them, and moreover the character of the fauna points to a higher position in the series.

Horizon.

The fossils collected from these shales were submitted to Mr. Cowper Reed for description, and his determination of them has appeared in the Memoir on the Devonian Faunas of the N. Shan States already cited (page 157, *seq*). The following is a list of the species (Table 9):—

E tent.

Table 9.

List and Distribution of Wetwin Fauna.

TABLE 9.

List and Distribution of

NAME.	NEAREST ALLIES.
BRYOZOA.	
Fenestella polyporata Phill., var. **wetwinensis** Reed .	—
Fenestella sp.	*F. proceritas* Hall . *F. Morrisi* . .
Polypora sp.	*P. populata* Whidb. *P. hexagonalis* var. *foraminulosa* Hall.
BRACHIOPODA.	
Lingula cf. ligea Hall.	— *L. subparallela* Sandb.
,, cf. punctata Hall.	— *L. squamiformis* Phill. . .

Netwin Fauna.

DEVONIAN OF AMERICA.					Europe.	Remarks.
Lower.		Middle.	Upper.			
Helderberg Gr.	Corniferous Gr.	Hamilton Gr.	Portage Gr.	Chemung Gr.		
..	..	..	..	..	Carb., Ireland.	
..	×	..	..	..	..	
..	..	..	..	..	Carb., Ireland.	
..	..	..	..	..	Mid. Dev., Devonshire.	
..	×	..	..	..	..	
..	..	×	×	..	..	
..	..	..	..	..	Dev., Germany.	
..	..	×	..	—	..	
..	..	×	..	..	Mid. and Up. Dev., Britain.	

TABLE 9—*continued.*

List and Distribution of

NAME.	NEAREST ALLIES.
BRACHIOPODA—*contd.*	
Chonetes **subcancellata** Reed	*Ch. Logani* var. *aurora* Hall. *Ch.* cf. *nana* de Vern.
„ (?) sarcinulata Schloth	—
Rhynchonella (Camarotœchia sp. (A)	*Rh. Omaliusi, Rh. letiensis, Rh nux* Gosselet.
„ „ sp. (B)	*Rh. Gonthieri* Gosselet. *Rh. Horsfordi, Rh. Sappho, Rh. congregata* Hall.
Athyris cf. spiriferoides Eaton.	— *A. concentrica* v. Buch.

Wetwin Fauna—*continued.*

DEVONIAN OF AMERICA.					Europe.	Remarks.
Lower.		Middle.	Upper.			
Helderberg Gr.	Corniferous Gr.	Hamilton Gr.	Portage Gr.	Chemung Gr.		
..	..	×	..	..	..	
..	..	..	..	..	Mid. Dev., Poland	aff. *Ch. orientalis* v. Loczy, Dev., Yunnan.
..	..	..	..	..	Dev., Russia.	
..	..	..	..	..	Dev., Belgium, N. France.	
..	..	..	..	..	N. France.	
..	..	×	..	..	..	
..	×	×	..	..	..	
..	..	..	..	..	Dev., Europe.	

TABLE 9—*continued*.

List and Distribution of

NAME.	NEAREST ALLIES.
BRACHIOPODA—*concld.*	
Kayserella (?) sp.	(?) *K. lepidiformis* Gurich.
PELECYPODA.	
Janeira **birmanica** Reed.	*J. phaseolina* Goldf.
Phthonia **loczyi** Reed.	*Ph. nitida* Hall.
,, (?) cf. lirata Hall.	—
Prothyris (?) cf. lanceolata Hall.	—
Ontaria (?) sp.	—
Præcardium (?) sp.	—
Nucula **wetwinensis** Reed.	*N. Randalli*, *N. corbuliformis* Hall.

Wetwin Fauna—*continued.*

DEVONIAN OF AMERICA.					Europe.	Remarks.
Lower.		Middle.	Upper.			
Helderberg Gr.	Corniferous Gr.	Hamilton Gr.	Portage Gr.	Chemung Gr.		
..	..	..	..	..	Dev., Poland.	
..	..	..	..	..	Dev., Rhine.	
..	..	..	..	×	..	
..	..	×	..	..	..	
..	..	×	..	..	..	
..	..	..	..	..	..	A Devonian American genus.
..	..	..	..	..	..	A Devonian genus, Europe and America.
..	..	×	..	..	..	

TABLE 9—*continued.*

List and Distribution of

NAME.	NEAREST ALLIES.
PELECYPODA—*contd.*	
Nucula aff. niotica Hall.	—
,, cf. bellistriata Hall.	—
Palæoneilo cf. plana Hall.	—
,, cf. elongata Hall.	..
,, cf. sulcatina Conrad.	..
Paracyclas cf. proavia Goldf.	— *P. elliptica* Hall.
,, cf. rugosa Goldf.	— *P. lirata* Hall.

Wetwin Fauna—*continued.*

DEVONIAN OF AMERICA.						
LOWER.		MIDDLE	UPPER.		EUROPE.	REMARKS.
Helderberg Gr.	Corniferous Gr.	Hamilton Gr.	Portage Gr.	Chemung Gr.		
..	..	×	..	..	..	..
..	..	×	..	..	..	
..	..	×	..	×	..	
..	..	..	..	×	..	
..	..	..	..	..	..	Waverly Sandst. =(L. Carb.), America.
..	..	..	..	..	M. Dev., Europe.	
..	×	×	..	..	..	
..	..	..	..	..	Dev., Rhine.	
..	..	×	..	..	..	

TABLE 9—*concluded.*

List and Distribution of

NAME.	NEAREST ALLIES.
GASTROPODA.	
Bellerophon **shanensis** Reed.	*B. Hicksi* Whidb. . *B. neleus* Hall and Whitf.
,, (Phragmostoma) **admirandus** Reed. . .	*P. incisum* Clerke .
ARTHROPODA.	
Phaetonides aff. cyclurus Hall.	—
Echinocaris **asiatica** Reed.	*E. punctata* Hall. .
PISCES.	
Ichthyodorulite	—

Wetwin Fauna—*concluded.*

DEVONIAN OF AMERICA.						
LOWER.		MIDDLE.	UPPER.		EUROPE.	REMARKS.
Helderberg Gr.	Corniferous Gr.	Hamilton Gr.	Portage Gr.	Chemung Gr.		
..	..	..	..	..	M. Dev., Devonshire.	
..	..	..	..	×	..	
..	..	..	×	..	..	
×	..	..	..	..	..	
..	..	×	..	..	..	
..	..	..	..	..	..	Probably the dermal spine of an Acanthoid fish.

Conditions of deposition.

A glance at this table will show the complete dissimilarity that exists between the fauna of the Wetwin Shales and that of the Padaukpin coral-reef, not only in its composition but in its affinities. As Mr. Cowper Reed suggests (*Op. cit.*, p. 183) this difference may be due as much to bionomical surroundings as to a difference in age, and indeed it is evident that the two sets of beds must have been deposited under very different conditions. It seems probable that the shales were accumulated in a lagoon which may have had only a slight connection with the open sea, and in respect to this supposition it is interesting to note that a portion of the shales is highly impregnated with iron ore, which may have originated, as so often happens, in a shallow swamp or lagoon. The deposition of the shales may, indeed, have been contemporaneous with that of the coral reef close by.

Composition and affinities of fauna.

The most striking characters of this fauna, as compared with that of Padaukpin, are the prevalence of lamellibranchs, and the close relationship with American forms, especially those belonging to the Hamilton, or middle Devonian group of that country. The occurrence of the almost exclusively American genus *Palæoneilo*, which, as we will see, flourished also at a much later date in the Shan seas, is the most conspicuous instance of this affinity, but the fauna as a whole bears traces of it, no less than 24 out of the 30 species described from Wetwin, being compared by Mr. Cowper Reed with American forms.[1] Indeed it seems to me not at all unlikely that, if the fauna of the Plateau Limestone had not been so completely destroyed, we would find that there was in reality not nearly so close a resemblance with the European Devonian type of fauna as the sporadic occurrence at Padaukpin would indicate.

Other bands of shale.

The Wetwin shales are not the only bands of the kind that occur among the limestones of the plateau, though this particular fauna has not been brought to light elsewhere. Indeed, shaly bands may be much more frequent than one would suppose, for their outcrops are apt to be washed out and filled in with the universal red clay that covers the ground. It is therefore only in fresh cuttings on the railway or road that they are likely to be found. At the same time sections like that in the Gokteik gorge, where there is a

[1] F. R. Cowper Reed, Pre-Carboniferous Life-Provinces; *Records, Geol. Surv. Ind.*, Vol. XL, Pt. 1, p. 31.

continuous series of cuttings extending for several miles, show that there may be none of these bands in a very great thickness of limestone.

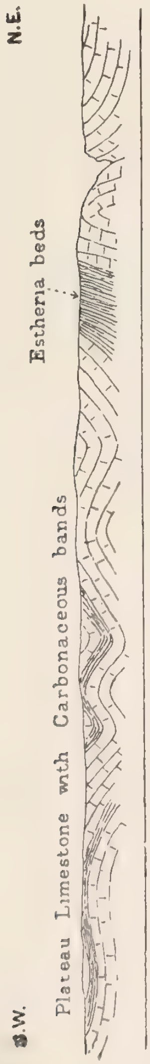


FIG. 6.—Section near Loi-hkaw, showing position of Estheria Beds. Length of Section about 400 yards. Not drawn to scale.

Shale band at Letkaung.

One such cutting on the railway occurs a little to the west of Letkaung village, at the foot of the final ascent to Maymyo (Loc. 26, 4), where some slightly carbonaceous shales are interbedded with the limestones, dipping N. E. at an angle of 17 degrees, and contain specimens of a small *Lingula* and other fossils, none of which, however, are specifically determinable. Another band of shale was found in a cutting about three miles east of Kyaukmé station (Loc. 31, **E** 2), greatly contorted and in places vertical, portions of which were found to contain the shells of a minute *Estheria*, somewhat resembling *E. mangiliensis* Rupert Jones, from the Panchet beds of the Indian Gondwanas, according to Mr. Cowper Reed, as well as some very fragmentary plant remains (Fig. 6). Portions of this band also are carbonaceous, and it is indeed not unusual to find strings and pockets of coaly matter among the Plateau Limestones.

Carbonaceous layers.

One of these occurrences, which looked rather promising, was found close to Manhpwi (Mán-hpa) station (**G** 1), between Hsipaw and Lashio, and was carefully examined in 1904 by Mr. Datta, who traced the coaly layer for some distance, but was unable to find any seam of value as fuel. In fact, the sample analysed in the Geological Survey Laboratory was found to contain more ash than carbon.

CHAPTER X.

PLATEAU LIMESTONE.

Permo-Carboniferous or Anthracolithic Section.

Mode of occurrence and characters.

At various places on the Shan States plateau, especially towards the south-east, patches of a limestone of a character different from that constituting the great bulk of the formation are met with, usually as outlying masses, capping ridges and knolls with rugged precipitous walls of rock. These limestones are generally dark blue, grey or black in colour, with a much more strongly fetid odour than that of the limestones below. Although the microscope shows that the matrix of the rock is in all cases crystalline, the individual crystals are exceedingly minute, and the rock does not exhibit the sandy texture that is so characteristic of the ordinary Plateau Limestone, but is much more compact and often possesses a conchoidal fracture. In addition, these rocks are in many places highly fossiliferous, and in most cases the microscope reveals in thin sections the presence of minute fragments of shells, or of foraminifera of various kinds.

Boundary uncertain.

It has been found impossible to show these patches of rock on the map attached to this Memoir, not only on account of its small scale, but also because of the difficulty of finding any definite line of division between them and the limestone beneath. On the plateau the difference in appearance is easily recognisable, and the boundaries of each patch are fairly well defined, but I was fortunate enough to discover a number of specimens of *Fusulina elongata* at Tonbô (Loc. 27, **B** 5), at the extreme western edge of the hills, in a band of limestone which appeared to pass laterally, as well as vertically, into crystalline limestone indistinguishable from the usual type; and it is therefore by no means certain that there is any noticeable difference in age between these compact, dark coloured rocks and the upper part of the ordinary Plateau Limestone.

Conditions of depositions.

It may be that the change of character is not so much due to a difference in age as either to some local peculiarity in the conditions of accumula-

tion of the sediment, resulting in a particular assemblage of organisms; or perhaps to a difference in the treatment to which the last beds to be accumulated were subjected after their deposition, as compared with the remainder. On the one hand, these patches may have been of the nature of reefs, supporting an abundant brachiopod and coral fauna, while the surrounding sea was occupied mainly by mollusca, with their more easily decomposed shell structure; that is to say, the conditions that gave rise to the Devonian reef of Padaukpin may have been repeated at this period. On the other hand, the fact that these highest beds, as shown by the chemical analyses given in Table 7 (p. 188), are composed of practically pure carbonate of lime, whereas the whole of the mass underlying them has been converted into a dolomitic limestone, indicates a complete change in the history of this portion of the formation; perhaps, as I have already suggested (p. 193), a replacement of the long-continued subsidence which must have accompanied the deposition of so enormous a thickness of rock by a somewhat rapid upheaval. For these reasons I have made no distinction between these rocks and the Plateau Limestone for the present, but it will probably be found that when the Southern Shan States are geologically surveyed, it will be possible to map them as a separate formation.

Probable erosion before deposition of overlying beds.

It may be remarked that no trace of these upper limestones has been found along the edge of the tongue of Plateau Limestone extending northwards along the east bank of the Nám-Tu, where the latter appears to dip conformably below the red Jurassic sandstones; but as there was certainly some denudation of the limestone before the Namyau series was deposited, the topmost beds may have been swept away during the interval. At Kehsi Mansam, in the extreme south east of our area, the Permo-Carboniferous beds are seen almost in contact with the red sandstones, but the section at that place, to be described below, is on the line of a fault and greatly confused, and the exact relations between the two sets of beds are not clearly seen.

Occurrence in S. Shan States.

The first discovery of fossils in these rocks was made in 1899 by Mr. C. S. Middlemiss, in the Southern Shan States, where they are evidently more highly developed than in the Northern States. In fact they do not occur at all on the line of the Mandalay

Lashio railway traversed by Mr. Datta and myself in the same year, except at Tonbô, where it was not till several years afterwards that *Fusulina* was discovered; but they become more and more prominent as we proceed from the line of the railway towards the south and south-east.

Situation and characters of beds.

Mr. Middlemiss' find is described in the General Report, *Geol. Surv. Ind.*, for 1899-1900, p. 137 *et seq.* The fossils were collected from a series of thin banded, shaly and marly limestones, extending along the Government cart-road leading eastwards from Taunggyi, the head-quarters station, from a point about 20 miles east of that place to Mong Pawn, a distance of about 10 miles. They are generally to be found lying loosely on the weathered surface of the rocks, as at Padaukpin, and among them Mr. Middlemiss was able to recognise such well known Salt Range forms as *Athyris* (*Spirigera*) *Royssii* L'Ev., *Spirigerella Derbyi* Waag., *Chonetes grandicosta* Waag., etc., and to correlate the beds with the middle Productus Limestone of that area, an opinion which has since been amply confirmed by Dr. C. Diener, who has examined and described the Anthracolithic fauna of this region.[1]

Fossils.

Original discovery of fossils.

In the Northern Shan States the presence of rocks belonging to this horizon was first discovered by Mr. P. N. Datta, who in 1901 notified the occurrence of *Fusulina* in a limestone band at the crest of a ridge a few miles west of Tong-Ang ferry on the Nám-Tu (Loc. 32, **F** 3), and still further to the east at Ho-un (Loc. 35, **H** 3). A few badly preserved shells were also collected by him near Mankang on the north slope of the Loi-len range (Loc. 33, **H** 1). Subsequently other exposures of limestone with *Fusulina* were found, and in addition a fairly rich brachiopod and bryozoan fauna, which has, in the hands of Dr. Diener, proved the existence of strata of Permo-Carboniferous or Anthracolithic age over a large area in these States.

Fossil localities.

The fossils described by Dr. Diener were collected at three widely separated localities, only one of which, Namún (Loc. 34, **G** 3), is actually situated in the Northern States, and is therefore, strictly speaking, included within the area now being described; but Kehsi Man-

[1] The Anthracolithic fossils of the Northern Shan, States; *Pal. Ind.*, New Ser., Vol. III., Mem. No. 4.

sam (Loc. 37, **H** 5), the capital of the State of that name, where the most abundant and varied fauna was found, is not far from the borders of the Northern States, and after all the boundary is drawn merely for administrative purposes, and bears a very slight relation to the physical configuration of the country, much less to its geological features. The third locality comprises the collections made by Mr. Middlemiss during his traverse along the cart-road east of Taunggyi, introduced here for purposes of comparison.

Fig. 7.—Section in Nam-Hen at Kehsi Mansam.

1. Plateau Limestone. 2. Fusulina and Productus Beds. 3. Namyau Beds. F. Faults.

Length of Section about $\frac{3}{4}$ miles.

Not drawn to scale.

Section at Kehsi Mansam (Fig. 7).

The section of these rocks exposed at Kehsi Mansam is by no means so complete as that described by Mr. Middlemiss, but contains a richer assemblage of fossils. It is situated about a mile to the south-west of the town, in the bed of the Nám-Hen river, and about a quarter of a mile above the bridge on the cart-road leading to Möng Tung. At the bridge, and for a short distance above it, a series of red sandstones and shales, with slightly carbonaceous layers, is exposed on the left bank, dipping generally in a southerly direction, but greatly contorted, especially towards the upper end of the section. These beds probably belong to the Mesozoic Namyau series. Immediately to the south of these, and apparently higher in the section, are some limestones with obscure traces of (?) *Fusulina*, but these may not

be *in situ* or are brought up by a fault. The whole section is on the line of a considerable fault which traverses the older rocks to the west, and the contortion seen in the red beds is no doubt due to movement along the fault-plane. Beyond this the whole of the rocks are concealed, for a distance of several hundred yards, by a calcareous dam extending across the river and a deep pool, above which the fossiliferous rocks appear.

Productus and Fusulina limestones.

These consist of dark grey or black limestones, dipping steadily to the south at about 25°, in thin bedded layers, one of which at least is made up almost entirely of *Fusulina elongata* (Plate 14, Fig. 1), while other layers contain large numbers of brachiopods. These rocks continue, all dipping in the same direction, for about another quarter of a mile, when they abut against massive beds of the ordinary Plateau Limestone, dipping in the opposite direction, that is to say to the north, at a high angle. The last beds of the Anthracolithic series seen are massive and hard blue limestones dipping directly towards the older rocks.

Faulted boundaries.

Down stream, beyond the red sandstones exposed at and below the bridge, the Plateau Limestone also appears in the bed of the river, and it therefore seems probable that the Fusulina beds and overlying strata have been let down between two parallel faults, becoming much folded and crushed in the process.

Coral limestones.

A few scattered masses of hard blue limestone, similar to the uppermost beds seen in the river section, were noticed in the valley of a small side stream falling into the Nám-Hen below the bridge. These exhibit numerous examples of brachiopoda, bryozoa, and corals on the weathered surface and in section (Plate 14, Fig. 2), but it was found almost impossible to break them off without damage.

Outcrop at Namún.

The collection of Namún was made from a small outcrop of dark grey limestone, weathering to a rusty yellow, exposed on the path running along the northern flank of Loi Pan from Möngkhô to Mánpan, near the crest of a low rise half a mile to the north-east of the village of Namún. The rock *in situ* is crowded with fossils, mainly bryozoa, but they are only to be obtained on the surface of weathered fragments or by washing the clay derived from the outcrop, as at Padaukpin. The whole exposure does not cover a space of more than 3 or 4 square yards, and the bedding is very indistinct,

but is probably nearly horizontal. Several large masses of the hard blue limestone in which *Fusulina* are usually found occur close by, but the ground is so densely covered with vegetation, except along the path, that the relation of these masses to the beds with bryozoa could not be made out. The locality is within a mile of the slates and quartzites of the Chaung-Magyi series at the foot of Loi Pan, and the only rocks to be seen in the intervening ground are a few outcrops of the ordinary Plateau Limestone.

Blue limestone.

The third locality, Mong Pawn, is the one described by Mr. Middlemiss in the General Report for 1899-1900 already cited. The fossils usually occur in thin-bedded, concretionary tabular limestones with marly or shaly layers, exposed at various points along the road from the 20th to the 30th mile east of Taunggyi. Their manner of weathering, etc., is exactly the same as at Namún, and as Mr. Middlemiss remarks, the best method of search is to wander along the cuttings and pick out the fossils, chiefly brachiopoda, from the crumbling surface of the beds. The position of the fossiliferous strata here is the same as in the northern States, *viz.*, resting upon a series of massive white and grey limestones, often greatly brecciated, which I have no hesitation in identifying with the ordinary Plateau Limestone of this Memoir.

Occurrence in S. Shan States.

In addition to these localities, beds containing *Fusulina elongata*, associated with corals and sometimes with brachiopoda, but in too ill-preserved or fragmental a state for identification, have been found at several other places in the Northern Shan States, in patches of limestone that indicate, by their mode of occurrence, the former widespread extension of this formation over the plateau. I have already mentioned their occurrence at Tonbô, at the edge of the Irrawaddy valley, 13 miles to the south-east of Mandalay. They have not been met with between this place and the valley of the Nám-Tu south of Hsipaw, a distance of about 80 miles, but further to the east exposures of these limestones become more frequent. Several large masses were found at Manmaw (Loc. 36, **H** 3), in the valley of the Nám-Lawng river, and a broken line of outcrops of the same rock has been traced northwards from the neighbourhood of this place for some 12 miles, forming a low but well defined ridge. At Manmaw some shelly limestones also occur with badly preserved *Productus*, *Spirifer*, etc.

Other localities.

Similar masses were also found across the Nám-Lawng on the crests of the ridges about Mán-pung, (I 3) and again still further east on a ridge to the south-west of Mán Hpai (I 4), where bryozoa are fairly numerous. Finally, a band of reddish limestone, crowded with *Fusulina elongata*, resembling the Fusulina band at Kehsi Mansam, was discovered by Mr. Coggin Brown at the Natural Bridge on the Nám Lan river, one of the southern tributaries of the Nám-Tu, near Naniô (F 4). Here the Fusulina band rests on the ordinary Plateau Limestone, and is succeeded above by red shales belonging to the Namyau series, faulted against the Plateau Limestone as at Kehsi Mansam.

Limestones of doubtful age.

On examining thin sections of the limestones collected in the Shan States under the microscope, I have found that certain blue limestones, which I had thought, from their apparent position in the field, should be included with the next overlying group, the Rhætic or Napeng beds, contain poorly preserved fragments of a *Fusulina*, not specifically determinable, but differing in shape and in the internal arrangement of the cells from *F. elongata*. These limestones are exposed in the bed of the Nám-Tu at Htengnoi (F 3), and the beds were traced for two or three miles to the north of that place towards Nawnghkio. They are well seen in the bed of the river above Htengnoi, where they dip to the E. or S.E. at angles of 20 to 30 degrees. They extend for about half a mile up the river, and are apparently succeeded below by thick beds of conglomerate, which in turn rest upon steeply inclined beds of the massive Plateau Limestone. It was on account of these conglomerates, which contain well rolled pebbles of the Plateau Limestone, that I mapped the blue limestones as belonging to the Napeng beds; but as they are now found to contain *Fusulina* they are probably older. As usual the section is incomplete, and the conglomerates are not actually seen to underlie the blue limestones, but occur in detached masses which may have been let down from a higher level by the solution of the limestone beneath. Further exploration of the neighbourhood is necessary before the relations of the rocks in this interesting section can be made out.

Section at Htengnoi.

The peculiar oolitic limestone, a section of which is shown in Plate 15, fig. 1, occurs lower down the valley near the village of Na-aw, and appears to be near the horizon of the Fusulina beds of

Htengnoi. But some of the limestones associated with the Napeng beds are very similar, as, for instance, the specimen from Loi-lam (Loc. 23, E 3), a section of which is shown in Plate 15, fig. 2. The Na-aw rock is crowded with elongated, oval, oolitic granules, and contains in addition numbers of minute shells, and the spines of echinoderms.

List of fossils.

The fossils collected at the three localities mentioned above, and described by Dr. Diener, are enumerated in the following list (Table 10), which also shows the distribution of the species in other zoogeographical provinces. This brings out the strong resemblance that exists between the Anthracolithic fauna of the Shan States and that of the Productus Limestones of the Salt Range in the Punjab and of the Central Himalaya, and points at once to a great change of some kind in the conditions that, up to this period, affected the relations between the faunas of the northern and eastern coasts of Gondwanaland.

Permo-Carboniferous transgression.

The almost universal transgression of the Permo-Carboniferous sea that took place at this time is a well established fact, but how and where the barrier was broken down in this region is not quite clear. Indications have been met with that the Permo-Carboniferous sea extended along the northern side of the present line of the Himalaya as far east as the longitude of Assam; for Dr. J. M. Maclaren[1] discovered, in some boulders brought down by the Subansiri river in that province, a fauna which has been described by Dr. Diener,[2] and was found to include such undoubted Anthracolithic forms as *Productus* cf. *pustulosus* Phill., *Chonetes* cf. *carbonifera* Keys., a *Dielasma* allied to *D. biplex* Waag., *Reticularia* cf. *inæquilateralis* Gemm., etc. And since Permo-Carboniferous rocks are known not to occur in association with the belt of Gondwana sandstone that runs along the flanks of the Himalaya on the north side of the Assam valley,[3] it is probable that the boulders in which these fossils were found come from the upper part of the Subansiri gorge, beyond the main axis of the range. But it would have required an entire submergence of the barrier to the north of Burma

[1] Geology of Upper Assam; *Records, Geol. Surv. Ind.*, Vol. XXXI, Pt. 4, p. 186.

[2] Subansiri Fossils; *Ibid*, Vol. XXXII, Pt. 3, pp. 189—198.

[3] F. R. Mallet, Geology of Darjiling and the Western Duars; *Memoirs, Geol. Surv. Ind.*, Vol. XI, Pt. 1, p. 14: H. H. Godwin Austen, Geology of part of the Dafla Hills; *Journ. As. Soc. Bengal*, Vol. XLIV, Pt. 2, p. 37: T. D. LaTouche, Geology of the Aka Hills; *Records, Geol. Surv. Ind.*, Vol. XVIII, Pt. 2, p. 121.

to complete the connection, and we have no evidence that such a submergence ever took place. At the same time no traces of marine strata belonging to this period have been discovered to the east of the Salt Range in the Punjab, on either side of the valley of the Ganges or its tributaries. It must, however, be remembered that we have no knowledge whatever of the strata that underlie the Ganges alluvium; and I am by no means convinced that a direct communication may not have been opened up between the seas of the Punjab and of Burma at this time. I will return to this question in a future chapter (p. 351 *seq.*); but at present it will be sufficient to say that the very close similarity between the Middle Productus fauna of the Salt Range and that of the Shan States seems to require a more direct connection between the respective seas than would be afforded by a communication by way of the northern branch of the 'Tethys' alone.

Possible connection south of the Himalaya.

The distribution of the fauna, when compared with that of the same period in other regions, presents some interesting points. There is a striking connection with the Permian and Carboniferous faunas of Russia, 29 out of the 78 Shan species being identical or closely allied; but this was only to be expected, in consideration of the resemblance that is known to exist between the Permo-Carboniferous Salt Range fauna and that of the Ural. On the other hand, this list would seem to show that there was no very close connection between the Shan and China seas, only seven species being common; but the facies of the fauna is the same in the two areas, and as v. Loczy[1] has shown that the Chinese fauna was nearly related to that of the Salt Range and of the Ural, further exploration of the intervening country will probably reveal a closer resemblance between the faunas of China and the Shan States than now appears to exist. Limestones belonging to this period have been found in Yunnan, and in the adjoining district of Batang in Western Sze-chuan, but they do not appear to have extended into north-eastern China, where the Carboniferous limestones are succeeded by red sandstones of a continental type, of Permo-Triassic age.[2]

Affinities of Anthracolithic fauna.

Extension into China.

[1] Reise des Grafen Bela Szechenyi in Ostasien, Vol. III, p. 175 *et seq.*
[2] Bailey Willis, Research in China, Vol. II, Chap. VI.

Table 10.

List and distribution of Anthracolithic Fauna.

TABLE 10.

List and distribution of Anthra

Names.	Asia. Shan States. Kehsi Mansam.	Shan States. Namún.	Shan States. Mông Pawn.	Salt Range. Productus Limestone. Lower.	Salt Range. Productus Limestone. Middle.	Salt Range. Productus Limestone. Upper.	Central Himalaya.	Armenia.
FORAMINIFERA.								
Fusulina elongata Shumard	×	..	..	..	..	..	..	..
ANTHOZOA.								
Lonsdaleia indica Waag. and Wentz.	×	..	..	..	×	×	..	..
Amplexus sp. ind.	×	..	×	..	..	..	..	..
Zaphrentis sp. ind.	×	..	..	..	..	..	..	..
Syringopora sp. ind.	×	..	..	..	..	..	..	..
Michelinia (?) sp. ind.	..	..	×	..	..	..	..	..
Cyathaxonia sp. ind.	..	..	×	..	..	..	..	..
CRINOIDEA.								
Indeterminate crinoid stems	×	×	×	..	..	..	..	..

colithic Fauna.

		EUROPE.			AMERICA.		AUSTRALASIA.		
TIAN SHAN.	CHINA.	RUSSIA.	W. EUROPE.	MEDITERRANEAN.	NORTH.	SOUTH.	TIMOR.	AUSTRALIA.	REMARKS.
..	..	..	..	..	×	..	..	..	Occurs in Afghanistan.
..	? ×	..	..	×	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	

TABLE 10—*continued.*

List and distribution of Anthra

Names.	Asia.							
	Shan States.			Salt Range. Productus Limestone.			Central Himalaya.	Armenia.
	Kehsi Mansam.	Namún.	Möng Pawn.	Lower.	Middle.	Upper.		
Bryozoa.								
Hexagonella ramosa Waag. and Wentz.	..	×	..	..	×	×	..	..
Geinitzella cf. columnaris Schloth.	..	×	..	..	×	×	..	..
Fenestella cf. perelegans Meek.	..	×	..	..	×	..	..	..
,, sp. ind. aff. Geinitzi d'Orb.	..	×	..	..	..	..	..	..
,, sp. ind.	×	×	..	..	..	..	..	..
Polypora cf. ornata Waag. and Pichl.	..	×	..	..	×	×	..	..
,, cf. biarmica Keyserl.	..	×	..	..	..	×	..	..
,, cf. megastoma de Kon.	..	×	..	..	×	..	..	..
,, sp. ind. aff. Kolwae Stuck.	..	×	..	..	..	..	..	..
,, sp. ind. aff. ufimiana Stuck.	..	×	..	..	..	..	..	..
,, sp. ind.	×	×	..	..	..	..	..	..
,, (?) sp. ind. aff. Sykessi de Kon.	..	×	..	..	×	..	..	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
TIAN SHAN.	CHINA.	RUSSIA.	W. EUROPE.	MEDITERRANEAN.	NORTH.	SOUTH.	TIMOR.	AUSTRALIA.	REMARKS.
..	..	..	..	..	..	..	..	..	
..	..	×	..	..	..	..	..	..	
..	..	..	..	..	×	..	..	..	
..	..	..	×	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	×	..	..	×	..	..	..	
..	..	×	..	..	..	..	..	..	
..	..	×	..	..	..	..	..	..	
..	..	×	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..		

TABLE 10—*continued.*

List and distribution of Anthra

Names.	ASIA.							
	Shan States.			Salt Range. Productus Limestone.			Central Himalaya.	Armenia.
	Kehsi Mansam.	Namún.	Möng Pawn.	Lower.	Middle.	Upper.		
Brachiopoda.								
Spirifer fasciger Keyserl.	×	×	×	×	×	×	×	..
„ striatus Martin.	×	..	..	×	..	..	..	..
„ sp. ind. aff. striato Martin.	..	×	..	..	..	..	..	..
„ condor d'Orb.	×	..	..	..	..	..	..	..
Martinia **dispar** Dien.	×	..	..	..	..	..	..	..
„ sp. ind.	..	×	×	..	..	..	..	..
„ orbicularis Gemm.	×	..	..	..	..	..	..	..
Reticularia cf. lineata Martin.	×	..	..	×	..	..	×	×
Martiniopsis **Latouchei** Dien.	×	..	..	..	..	..	..	..
Spiriferina cristata Schloth.	×	×	?×	×	×	×	×	..
„ n. sp. ex aff. Sp. laminosæ mut. sterlitamakensis Tschern.	×	..	..	..	..	..	..	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
Tian Shan.	China.	Russia.	W. Europe.	Mediterranean.	North.	South.	Timor.	Australia.	Remarks.
? ×	..	×	..	×	..	..	..	..	=*Sp. musakhelensis* Dav.
..	..	×	×	..	..	..	..	? ×	
..	..	..	..	..	..	..	..	..	
..	..	×	..	..	..	×	..	..	
..	..	..	..	..	..	..	..	..	cf. *Sp. Sokolowi* Tschorn., U. Carb., Ural.
..	..	..	..	..	..	..	..	..	
..	..	×	..	×	..	..	..	..	
×	×	×	×	×	×	..	×	×	
..	..	..	..	..	..	..	..	..	aff. { *M. inflata* Waag. / *M. subpentagonalis* Waag. } Salt Range.
×	..	×	×	×	..	..	×	×	
..	..	×	..	..	..	..	..	..	

TABLE 10—*continued.*

List and distribution of Anthra

Names.	Asia. Shan States. Kehsi Mansam.	Shan States. Namún.	Shan States. Möng Pawn.	Salt Range. Productus Limestone. Lower.	Salt Range. Productus Limestone. Middle.	Salt Range. Productus Limestone. Upper.	Central Himalaya.	Armenia.
BRACHIOPODA—*contd.*								
Spiriferella sp. ind. ex aff. Saranæ de Vern.	×	..	..	..	..	..	..	..
Spirigera Royssii L'Ev.	×	..	×	? ×	×	×	×	..
Spirigerella Derbyi Waag.	×	..	×	..	×	×	×	..
,, n. sp. aff. numismalis Waag.	×	..	..	×	..	..	..	..
Hustedia remota Eichw.	×	..	..	×	×	×	×	..
Streptorhynchus shanensis Dien.	×	..	..	..	..	..	..	..
,, cf. semiplanus Waag.	..	×	..	..	..	×	..	..
,, (?) sp. ind.	×	×	..	..	..	..	..	..
Schizophoria indica Waag.	..	×	..	×	×	..	..	..
,, cf. indica Waag.	×	..	×	..	..	..	..	..
Rhynchonella imitatrix Dien.	×	..	..	..	..	..	..	..
,, Michelinii L'Ev.	..	×	..	..	..	..	..	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		Remarks.
Tian Shan.	China.	Russia.	W. Europe.	Mediterranean.	North.	South.	Timor.	Australia.	
..	..	×	..	..	..	..	..	..	
? ×	? ×	..	×	..	..	×	×	×	
..	..	..	..	..	×	..	..	..	
..	..	..	..	..	..	..	..	..	
..	×	×	..	..	..	..	..	×	
..	..	..	..	..	..	..	..	..	
..	..	..	..	×	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	aff. { *Rh. dubia* Hall, N. America. *Rh. incisiva* Waag., Salt Range.
..	..	×	×	..	×	..	..	..	

TABLE 10—*continued.*

List and distribution of Anthra

NAMES.	ASIA. Shan States. Kehsi Mansam.	ASIA. Shan States. Namún.	ASIA. Shan States. Möng Pawn.	ASIA. Salt Range. Productus Limestone. Lower.	ASIA. Salt Range. Productus Limestone. Middle.	ASIA. Salt Range. Productus Limestone. Upper.	ASIA. Central Himalaya.	ASIA. Armenia.
BRACHIOPODA—*contd.*								
Oldhamina cf. decipiens de Kon.	×	..	..	..	×	×	..	..
Productus Cora d'Orb.	×	..	..	×	×	×	×	..
,, tenuistriatus de Vern.	×	..	..	..	..	..	..	..
,, Wallacei Derby var. burmana Dien.	×	..	..	..	..	..	..	..
,, gratiosus Waag.	×	..	..	..	×	×	×	×
,, cf. inflatus McChesney	×	..	..	..	..	..	..	..
,, cf. boliviensis d'Orb.	×	×	×	..	..	..	..	..
,, sp. ind. aff. porrecto Kut.	×	..	..	..	..	..	..	..
,, cf. nebrascensis Owen.	×	..	..	..	..	..	..	..
,, Abichi Waag.	×	..	..	..	×	×	×	×
,, cylindricus Waag.	×	..	..	..	..	×	..	..
,, sp. ind. aff. mammato Keyserl.	×	..	..	..	..	..	..	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
Tian Shan.	China.	Russia.	W. Europe.	Mediterranean.	North.	South.	Timor.	Australia.	Remarks.
..	..	..	..	..	..	..	..	..	
×	×	×	×	×	×	×	..	×	
×	..	×	..	..	..	..	..	..	
..	..	×	..	..	..	×	..	..	
×	..	..	..	×	..	..	×	..	
×	..	×	..	×	×	..	..	..	
..	..	×	..	..	..	×	..	..	
..	..	×	..	..	..	..	..	..	
..	..	..	..	..	×	..	..	..	
..	..	..	..	..	..	..	×	..	
..	..	..	..	..	..	..	..	..	
×	..	..	..	..	..	..	..	..	

TABLE 10—*continued.*

List and distribution of Anthra

Names.	ASIA.							
	Shan States.			Salt Range. Productus Limestone.			Central Himalaya.	Armenia.
	Kehsi Mansam.	Namún.	Möng Pawn.	Lower.	Middle.	Upper.		
Brachiopoda—*contd.*								
Productus cf. pustulatus Keyserl.	..	×	..	..	..	..	..	..
" sp. ind.	..	×	..	..	..	..	..	..
" sp. ind.	..	×	..	..	..	..	..	..
Strophalosia costata Waag.	×	..	..	×	? .	..	..	..
" sp. ind. cf. indica Waag	×	..	..	..	..	×	..	..
" cf. horrescens de Vern	×	..	..	..	×	..	..	..
" sp. ind. aff. plicosæ Waag	..	×	..	×	..	..	..	..
Chonetes sp. ind. aff. squamulifera Waag	..	×	..	..	×	×	..	..
" cf. lævis Dav.	..	×	×	..	..	..	×	..
" cf. variolata d'Orb.	..	×	..	..	..	..	..	..
" grandicosta Waag.	..	..	×	..	..	×	×	..
Uncinulus cf. timorensis Beyr.	..	..	×	..	? ×	×	×	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
TIAN SHAN.	CHINA.	RUSSIA.	W. EUROPE.	MEDITERRANEAN.	NORTH.	SOUTH.	TIMOR.	AUSTRALIA.	REMARKS.
×	..	×	×	×	..	..	..	..	
..	..	..	..	..	..	..	..	..	Group of *P. scabriculus* Martin.
..	..	..	..	..	..	..	..	..	Group of *P. spinulosus* Sow.(?)
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	×	×	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	aff. *Ch. permiana*, Shum., Texas.
..	..	×	..	..	×	×	..	..	
..	..	..	..	..	..	..	..	..	
..	×	..	..	..	..	..	×	..	

TABLE 10—*continued.*

List and distribution of Anthra

Names.	ASIA.							
	Shan States.			Salt Range. Productus Limestone.			Central Himalaya.	Armenia.
	Kehsi Mansam.	Namún.	Möng Pawn.	Lower.	Middle.	Upper.		
Brachiopoda—*concld.*								
Dielasma biplex Waag.	×	..	..	..	×	..	×	..
,, plica Kut.	..	..	×	..	..	..	×	..
,, sp. ind.	..	..	×	..	..	..	..	..
Notothyris simplex Waag.	×	..	..	..	×	..	..	..
,, nucleolus Kut.	..	×	..	..	..	..	×	..
Camarophoria cf. Purdoni Dav.	×	..	..	..	×?	×	×	..
Marginifera sp. ind. aff. helica Abich.	..	..	×	..	..	..	..	×
,, sp. ind. aff. typica Waag. (?)	..	..	×	..	×	×	..	..
Pelecypoda.								
Pseudomonotis sp. ind.	×	..	..	..	..	..	..	..

colithic Fauna—*continued.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
TIAN SHAN.	CHINA.	RUSSIA.	W. EUROPE.	MEDITERRANEAN.	NORTH.	SOUTH.	TIMOR.	AUSTRALIA.	REMARKS.
..	..	..	..	..	..	..	..	..	
..	..	×	..	? ×	..	..	..	..	
..	..	..	..	..	..	..	..	..	Group of *D. Gillingense* Dav.
..	..	..	..	..	..	..	..	..	aff. { *N. ovalis Gemm.*, Sicily. *N. nucleolus* Kut., Russia.
×	..	×	..	×	..	..	..	..	
..	×	..	..	..	..	..	..	..	aff. *C. mutabilis* Tschern., Russia.
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	

TABLE 10—*concluded.*

List and distribution of Anthra

Names.	Asia.							
	Shan States.			Salt Range. Productus Limestone.			Central Himalaya.	Armenia.
	Kehsi Mansam.	Namún.	Möng Pawn.	Lower.	Middle.	Upper.		
PELECYPODA—*contd.*								
Aviculopecten sp. ind. aff. subfimbriato de Vern.	..	×	..	..	..	..	..	..
SCAPHOPODA.								
Antale or Entalis (?) sp. ind.	×	..	..	..	..	..	..	..
ARTHROPODA.								
Phillipsia sp. ind. aff. Middlemissi Dien.	..	..	×	..	..	..	×	..

colithic Fauna—*concluded.*

		EUROPE.			AMERICA.		AUSTRALASIA.		
Tian Shan.	China.	Russia.	W. Europe.	Mediterranean.	North.	South.	Timor.	Australia.	Remarks.
..	..	×	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	
..	..	..	..	..	..	..	..	..	

Connection with America and the Malay Archipelago.

The occurrence of *Fusulina elongata* and of several bryozoa and brachiopoda, 14 species in all, shows that the connection with America indicated by the faunas of preceding periods was still kept up, and it is interesting to note that a small number of species agrees with those described by Prof. Rothpletz [1] from Timor and Rotti in the Malay Archipelago.

Composition of the fauna.

The composition of the fauna has been discussed by Dr. Diener, who calls attention to the importance of the brachiopoda, and to the significance of the occurrence at Kehsi Mansam of so peculiar a type, confined as it is to the Indian region, as *Oldhamina.* The list of species perhaps emphasises too strongly the difference between the faunas of Namún and Kehsi Mansam as regards the bryozoa, for these organisms are, I think, almost as numerous at the latter place as at Namún, but are preserved in such a way that only a very few and imperfect specimens could be collected.

Horizon.

As Dr. Diener says, the Anthracolithic beds of the Shan States must be placed on a level with the middle and upper Productus Limestones of the Salt Range and of the 'exotic block' of Chitichun No. 1 in the Central Himalaya. Of the 78 species described, 34 are common to our area and the Salt Range, of which 11 occur in the lower, 24 in the middle, and 22 in the upper division of the Productus Limestone respectively; while of those occurring in the two latter divisions 17 are common to both. As regards the Central Himalaya, 17 species are found in both areas, most of which are from Chitichun No. 1; and these include the only trilobite yet found in these rocks in Burma, a single specimen of *Phillipsia,* allied to *Ph. Middlemissi* Diener.

[1] Palæontographica, Vol. XXXIX, p. 62.

From a sketch by the author.

FIG. 8. The Gokteik Gorge, from the Natural Bridge.

CHAPTER XI.

RHÆTIC STAGE.

Interruption in sequence.

At the close of the Permo-Carboniferous period we meet for the first time with a really important break in the sequence of fossiliferous strata represented in the Shan States. There had been no doubt irregularities in the rate of deposition and in the distribution of the sediments over this region, but hitherto they appear to have been of a more or less local character, due to minor changes in the relative positions of land and sea; such, for instance, as that which has been supposed (*ante*, pp. 133, 179) to account for the local development of the Namhsim Sandstones and of the Zebingyi beds. But now we are confronted with a period during which deposition ceased entirely over the whole area dealt with, when it was raised above the sea level and subjected to atmospheric denudation.

Absence of Trias.

This period covers a great part of the Permian and the whole of the Trias, no strata of this age having yet been discovered in the Shan States; but even here there is evidence that the break was not a very wide-spread phenomenon, and that not far off to the north deposition was still going on. For Triassic rocks are known to occur in that direction in Yunnan, and Mr. Coggin Brown has found that in that country the Rhætic or Napeng beds of the Shan States, now to be described, are underlain by a series of red sandstones with coal seams and salt deposits, indicating the existence of a shallow sea in that direction.

Nature of movement.

It seems probable that, at the close of the great reef-building period represented by the Plateau Limestone, there was a 'negative' movement, causing the sea to desert this area, and resulting in a relative elevation of the recently formed reefs above the sea level, similar to that which has occurred in recent times in many parts of the Atlantic and Pacific. I need only cite the Fiji Islands, Cuba, and Barbados as instances of such a movement. It does not appear to have caused any dislocation or folding of the rocks, and may have done no more than raise the whole surface to a slight elevation above sea level; but it was sufficient to bring the limestones, already thoroughly

crystalline in structure and dolomitised, under the influence of subærial denuding agents, indicated by the presence of sporadic beds of coarse conglomerate, containing well-rolled pebbles of the limestone, as well as of the older rocks underlying it. These conglomerates have all the appearance of beach deposits, and may have been formed when the sea was again advancing.

Conglomerates.

Lithological characters.

When deposition again set in with the advance of the sea in Rhætic times, the beds laid down were of a very different character from those that had preceded them, and are very unevenly distributed. They are also variable in composition, but the prevailing type is a yellow or variegated, highly argillaceous shale or indurated clay, not unlike the Wetwin shales in appearance. In places they are impregnated with calcareous matter, and pass into clunchy, sandy marls, or tough argillaceous thin bedded limestones. Beds of a hard, dark blue limestone, indistinguishable, when it does not contain visible fossils, from some of the Permo Carboniferous limestones, are interstratified with the shales, especially at or near the base of the formation; but though these, as seen in thin sections, are crowded with fragments of shells, echinoid spines, and foraminifera (Plate 15, Fig. 2), the fossils are only occasionally to be seen weathered out on the surface, and these rocks have yielded nothing but a few corals, and those barely fit for determination.

Distribution.

The distribution of these beds is very capricious, patches of them having been met with at widely separated points over the Northern Shan States. They have not yet been found in the Southern States. Only one occurrence of them is known to the west of the Gokteik Gorge, *viz.*, at Kyaukkyan (Loc. 11, **D** 3), at the point where the railway crosses the great fault scarp between Hsum-Hsai (Thonzé) and the gorge. This outcrop was discovered in by Mr. Datta in 1900,[1] a short time after I had come upon another small patch of the same beds at Kyinsi or Hson-oi[2] (Loc. 13, **E** 2), close to the conflux of the Námhsim and Nám-Tu rivers near Bawgyô In the following year Mr. Datta discovered what has proved to be the largest and most extensively developed occurrence of these beds, the large area to the east and south-east of Napeng (Loc. 14, **E** 2, Locs. 15-22, **E** 3), a small village after which the formation has been

[1] General Report, *Geol. Surv. Ind.*, 1899-1900, p. 109.
[2] *Ibid*, p. 93.

named on account of the existence close to it of a very rich fossiliferous deposit, about nine miles to the east of Pyaunggaung railway station. Since then other outlying patches of the shales have been found, two of them far to the east on the southern flanks of the Loi-len range (Loc. 24, **I** 1, Loc. 25, **J** 1), and a third to the north, too small to be marked on the map, near Mán Sam (**F** 1), on the trade route leading north from Hsipaw. I have already pointed out (*ante*, p. 262) that the discovery of *Fusulina* in some of the limestones in the valley of the Nám-Tu near Htengnoi makes it doubtful whether the whole of the area coloured on the map as Napeng beds to the south of that place really belongs to this formation or not.

Relation to overlying beds.

The occurrence of these beds at Mán Sam is of special interest, as it is the only instance yet found in which the Napeng shales are associated with the overlying formation; though even here the section is so obscure that their exact relations could not be ascertained, in spite of an attempt made to expose them by excavation. It is, however improbable that any considerable break took place between the deposition of the Napeng and Namyau beds, and the general absence of the former along the boundary separating the latter from the Plateau Limestone must be explained on other grounds than partial denudation of a continuous formation.

Conditions of deposition.

If we consider the conditions that probably prevailed when the sea again invaded this area, after the Triassic break, I think that a simple explanation of the facts observed will appear. We have a wide expanse of coral reefs, raised for a period to a sufficient height above sea level to be exposed to denuding agents and worn into ridges and hollows, many of the latter perhaps cup-shaped depressions similar to those which are being formed at the present day. If an irregular surface of this kind were gradually covered by the waters of the sea, so as to be just awash, it would be natural that the sediment, most of it of an exceedingly fine character derived from the residue left by the degradation of the limestones still above water, would silt up the hollows, some of which might be at times cut off from communication with the open sea or from each other. In this manner the absence of these beds in positions where one would expect to find them is accounted for, without having to suppose that a temporary reversal of the downward movement, with consequent

denudation, took place; and at the same time this suggestion accounts for several peculiarities in the nature of the fauna, which have been found to be characteristic of the various isolated occurrences of these beds.

Influence of local conditions.

For instance, in the small patches under the Loi-len range at Lukhkai and Mán Kio, the fossils, though recognisable as belonging to the Napeng beds, are all ill-developed, possessed of extremely thin shells, and so stunted in size that they appeared to be hardly worth collecting; whereas many of the shells found in the broad Napeng area are of large size, and some of them, those of the *Gervillias* and *Myophorias* in particular, were evidently very massive. This difference may be accounted for on the supposition that the Lukhkai deposit was formed in a small, more or less isolated depression, in which suitable food was scarce.

'Sink-hole' at Nawngping.

Then again there is a very interesting occurrence near Nawngping (Loc. 12, **D** 3), the first station on the railway east of the Gokteik Gorge. At this spot, two miles north of the station, Mr. Datta discovered, in a 'borrow pit' beside the line, a bed of shale exactly resembling that of Napeng, but with a totally different assemblage of fossils, though there is no reason to suppose that they do not belong to the same period.[1] The most interesting forms are fragments of decapod crustacea, among which Dr. H. Woodward, to whom they were submitted, has recognised the remains of prawns and shrimps, but so imperfectly preserved that even the genera cannot be determined. Fragments of a large *Posidonomya*, specifically indeterminable, and a small *Lingula* are also present. Further excavations have been made at the spot both by Mr. Datta and myself, but we have not been able to discover either the extent or the thickness of the deposit. On the opposite side of the line, however, I found what appears to be the edge of a depression in which the clays may have been accumulated; for the surface of the Plateau Limestone, at the point where a low ridge composed of it abuts on the line, is covered with a calcareous deposit in which numerous casts of minute gastropods and some bivalves are embedded. At first sight these seemed to be weathered out of the limestone, but on examining thin sections of the latter under the microscope I could detect no trace of an organism, and moreover the fossils have been

Crustacean remains.

Ancient travertine deposit.

[1] General Report, *Geol. Surv. Ind.*, 1899-1900, p. 119.

shown to belong to a much later date than the limestone, and to be of either Rhætic or lower Jurassic age.[1] In fact, the fossiliferous part of the rock seems to be a coating of calcareous tufa or travertine, deposited in Rhætic or Jurassic times on the edges of a 'sink-hole' or 'pipe' in the limestone while the centre of the depression was being filled up by silt, on which the crustacea, etc., lived.[2]

Local disturbance of strata.

In the main area of these rocks, to the east and south-east of Napeng, they are frequently and highly disturbed and contorted in a most irregular manner. The beds are often horizontal or only slightly tilted for a space, but within a few yards they may be violently folded and crushed, as if they had been masticated between a giant pair of jaws or passed through a 'pug-mill.' This contortion of the strata is too irregular to be ascribed to a general earth thrust; and I think that a simple explanation of it may be found in the gradual underground solution of the limestone floor on which the formation rests, which has caused the shales to settle down in some places while remaining undisturbed in others. Mr. H. B. Medlicott has described, and explained in the same manner, a similar phenomenon at Cherra Punji in the Khasi Hills of Assam,[3] where upper Tertiary sandstones and shales, overlying a band of nummulitic limestone, have been let down and broken up by the dissolving away of the limestone beneath. Then again, if I am correct in thinking that the shales were accumulated in a depression in the limestone, it is not at all unlikely that the floor of the hollow was very irregular, and that when the rocks were again exposed to denudation, a good deal of slipping took place, which would account for much of the disturbed appearance of the beds.

Age of the formation.

The discovery of the Napeng fauna in the first instance aroused a considerable amount of controversy, echoes of which will be found in the General Reports for the years 1899 to 1903, among the officers of the Survey regarding the age of the beds. When Mr. Datta and I, the one at Kyaukkyan and the other at Kyinsi (Hson-oi), first came upon this fauna, we were both struck by its apparently Mesozoic facies;

[1] Miss M. Healey, The Fauna of the Napeng Beds or the Rhætic Beds of Upper Burma; *Pal. Indica*, New Series, Vol. II, Mem. No. 4, p. 87.

[2] On my last visit to this locality, in December 1906, none of these fossils were to be found. In the few years that had elapsed since the rock was exposed by the cutting made for the railway every trace of the old travertine deposit and of the fossils contained in it had been removed by weathering.

[3] The Coal of Assam; *Memoirs, Geol. Surv. Ind.*, Vol. IV, p. 424.

but when our collections reached Calcutta, our official palæontologist at that time, Dr. Noetling, recognising one or two specimens of *Conocardium* among them, affirmed the beds to be either of Devonian or Carboniferous age. It is due to Mr. Datta to say that he did not agree with this determination; and when in the following year he discovered the rich deposits of Napeng, and brought back a fine collection, including well preserved casts of a fossil which Dr. Noetling recognised as *Myophoria*, the beds were unhesitatingly referred to the Trias. Subsequently, however, Mr. C. L. Griesbach, then Director of the Survey, and Dr. Noetling visited the localities in person, and on the latter himself extracting a fossil which he declared to be an undoubted *Conocardium* (*see* General Report for 1901-02, p. 24), the original supposition, that the beds were Devonian, was reverted to, Mr. Datta still remaining in opposition. The question was not finally set at rest until, in 1903, I took a selection of the fossils to the International Geological Congress, held that year in Vienna, and submitted them to the inspection of several well known palæontologists. Even then there was a considerable divergence of opinion, but the detection by Prof. Ed. Suess, who with his customary urbanity was kind enough to devote some little time to a study of the collection of a species of Oyster (*Alectryonia*), showed at any rate that the fossils were Mesozoic; and that by Prof. Kossmat of the characteristic Rhætic species, *Pteria* (*Avicula*) *contorta*, determined without question the horizon to which they should be referred. The difficulty of arriving at a decision had been greatly enhanced by the fact that little or no assistance could be derived from stratigraphical evidence; for in no single occurrence were the relations of these beds to the Plateau Limestone clearly exposed. For instance, in the Plate attached to Mr. Datta's first account of the rocks (*see* General Report for 1899-1900, p. 96, figs. 7, 8, and 9), the Napeng beds, or Kyaukkyan Series as they were called in that report,—are shown as forming a synclinal passing under the limestones; and it was not until the actual boundary was exposed by excavation that it was found that the shales were let down against the limestone by a fault.

Characters of fauna.

In the end the collections were entrusted to Miss M. Healey, of Lady Margaret Hall, Oxford, for description, and the results of her researches were published in the *Palæontologia Indica* in 1908.[1] Miss Healey was able

[1] New Series, Vol. II, Mem. No. 4.

so confirm Dr. Noetling's identification of *Conocardium* among the tpecimens submitted to her, as well as the presence of two other genera which had survived from Palæozoic times, *viz.*, *Modiolopsis* and *Palæoneilo;* the latter an American genus which, as we have seen, was particularly abundant in the Devonian Wetwin Shales. There is indeed a very close lithological resemblance between the shales of Wetwin and the more argillaceous portions of the Napeng beds, and in the absence of fossils it would be quite impossible to distinguish between them. But, as Miss Healey remarks—

"the presence of *Palæoneilo* can cause no surprise since Bittner has shown that several species from St. Cassian belong to it." (*Op. cit.*, p. 3).

Moreover, the occurrence of *Pteria* (*Avicula*) *contorta* Portl., the zone fossil of the Rhætic, with *Grammatodon Lycettii* Moore and *Gervillia præcursor* Quenst., both characteristic fossils of the same horizon, as well as the presence of several species that closely resemble Rhætic forms, taken together with the clearly developed Mesozoic facies of the whole fauna, as shown by the abundance of such genera as *Myophoria, Pecten, Cardium*, etc., is more than sufficient to outweigh the evidence derived from the survival of one or two Palæozoic forms.

List of fossils.

The fossils described by Miss Healey are entered in Table 11 as having been collected at three localities, Kyaukkyan, Hson-oi, and Napeng. As a matter of fact those from the last named place were collected from a number of different spots, details of which will be found in the Tables attached to Miss Healey's Memoir (*Op. cit.* p. 88).[1] But as the beds are practically continuous over the area shown on the map, and almost certainly belong to one horizon, while there is hardly an outcrop exposed along the paths in any direction in which fossils may not be found, I have thought it unnecessary to repeat these details here. (Illustrations of a few of the new species are shown in Plate 27.)

[1] These are all situated within the square E 3 on the map, with the exception of Nawngleng (Loc. 14, E 2). The following are the names of the localities shown on the map:—

Loc. 15 Na-peng.
„ 16 Naunghkam.
„ 17 Nawnghkio.
„ 18 Námpen.
„ 19 Hkawkwo-lam.
„ 20 Na-nim.
„ 21 Nawngkwang.
„ 22 Námhu-ikkyi
„ 23 Loi-lam.

TABLE 11.

LIST OF NAPENG FAUNA.

TABLE 11.

List of the Napeng Fauna.

Name.	Napeng area.	Kyaukkyan.	Hson-oi.	Remarks.
ANTHOZOA.				
Lophosmilia **præcursor** Healey.	..	..	×	
Isastræa **confracta** Healey.	..	..	×	
BRACHIOPODA.				
Lingula **nanimensis** Healey.	×	..	..	cf. *L. zenkeni* Alberti, Trias; *L. borealis* Bittn., Trias, E. Siberia.
PELECYPODA.				
Palæoneilo **fibularis** Healey.	×	×	..	cf. *Leda Tatei* Newton, Lr. Lias, Arran; *L. Renevierei* Tate and Blake, Lias; *L. claviformis* Sow. Rhætic; *L. tenuistriata* Piette, Lias.
,, **nanimensis** Healey.	×	×	..	
,, **curvirostris** Healey.	×	..	..	
,, **Whitchurchii** Healey.	..	×	..	
,, sp. 1.	×	..	..	
,, sp. 2.	×	..	..	

,, (?) **incerta** Healey.	×	..	..	
Nucula **Peelii** Healey.	×	..	..	
,, sp. ind.	..	×	..	
Grammatodon Lycettii Moore.	×	..	..	Rhætic. cf. *Arca pumila* Dittmar Rhætic.
,, (Catella) **laticlava** Healey.	×	×	×	cf. *Arcoptera canaliculata* Kittl., Up. Muschelkalk, Saraievo.
Pinna cf. **Blanfordi** Boettg..	..	×	..	Rhætic, Sumatra.
Conocardium **superstes** Healey.	..	×	..	
,, (?) sp. ind.	..	×	..	
Gervillia **shaniorum** Healey.	×	..	..	
,, præcursor Quenst.	×	×	? ×	Rhætic, Europe.
,, **rugosa** Healey.	×	..	..	cf. *G. angusta* Goldf., Trias; *Avicula lanceolata* Sow. Lias.
,, **napengensis** Healey.	×	? ×	..	cf. *G. caudata* Winkl, Rhætic.
,, sp. 1.	×	..	..	cf. *Pteria pahangensis* Newton. Malay Peninsula.
,, sp. 2.	×	..	..	cf. *G. Wagneri* Winkl., Rhætic.
,, sp. 3.	×	..	..	
Hoernesia **filosa** Healey.	×	×	..	
,, sp. ind.	×	..	..	
Cassianella cf. subspeciosa Martin.	..	×	..	Rhætic.
,, sp. 1	×	..	? ×	
,, sp. 2	..	..	×	
,, sp. 3	..	×	..	
,, sp. 4	..	×	..	
Perna **obruta** Healey.	×	..	..	

TABLE 11.

List of the Napeng Fauna.

NAME.	NAPENG AREA.	KYAUKKYAN.	HSON-OI.	REMARKS.
PELECYPODA—*contd.*				
Perna sp. ind.	×	..	..	
Pteria (Avicula) contorta Portl.	×	×	×	Rhætic, Europe.
,, (,,) sp. ind.	×	..	..	
Alectryonia cf. Haidingeriana Emm.	×	..	×	Rhætic.
Myophoria **napengensis** Healey.	×	×	×	cf. *M. acuticostata* Broili and *M. harpa* Munst., Up. Trias; also *Hemicardium myophoria* Boettg., Rhætic, Sumatra.
,, **tenuis** Healey.	×	..	..	cf. *M. chenopus* Laube, Up. Trias.
,, cf. Emmerichii Winkl.	×	..	..	Rhætic.
Pecten (Synclonema) **quotidianus** Healey.	×	×	×	cf. *P. Helli*, Emm., Up. Trias; *P. filosus* Hauer, Raibl beds.
,, (Æquipecten) **Bayzandi** Healey.	×	..	..	
Plicatula **carinata** Healey.	×	..	..	
,, **difficilis** Healey.	×	..	..	
,, sp. ind.	×	..	..	

Placunopsis cf. Mortilleti Stopp.	×	..	..	*Anomia Mortilleti* Stopp., Rhætic.
Anomia **napengensis** Healey.	×	×	..	cf. *A. irregularis* Terq., Lr. Lias.
Modiolopsis **gonoides** Healey.	×	..	×	(?) cf. *Pleurophorus elongatus* Moore, Up. Trias, Malay Peninsula.
Modiola **frugi** Healey.	×	..	..	
,, sp. ind.	×	..	..	
,, (?) **dubia** Healey.	×	..	..	
,, (?) sp. 1	×	..	..	
,, (?) sp. 2	..	..	×	
,, (?) sp. 3	×	..	..	
,, (?) sp. 4	×	..	..	
Burmesia LaTouchei Healey.	×	..	..	
,, **lirata** Healey.	×	×	×	
Prolaria Sollasi Healey.	? ×	×	×	
Thracia **prisca** Healey.	×	×	×	
Cuspidaria sp. ind.	×	..	..	cf. *C. gladius* Laube, Up. Trias.
Datta oscillaris Healey.	×	..	..	
Astarte sp. ind.	×	..	..	
Isocyprina cf. Ewaldi Born.	×	..	..	Rhætic and Lias, Europe.
,, **manca** Healey.	×	..	..	
Cardita **singularis** Healey.	×	..	×	cf. *C. globiformis* Boettg. Rhætic, Sumatra.
Dentilucina **mona** Healey.	×	..	..	
Protocardia **contusa** Healey.	×	×	×	cf. *P. Choffati* Böhm, Lr. Lias, Portugal; *P. Phillippiana* Dumker, Lias.
Cardium **nequam** Healey.	×	×	×	cf. *C. reticulatum* v. Dittmar, Rhætic.
Anoplophora (?) **tenebricosa** Healey.	×	..	..	

TABLE 11.

List of the Napeng Fauna.

NAME.	NAPENG AREA.	KYAUKKYAN.	HSON-OL.	REMARKS.
SCAPHOPODA.				
Dentalium sp. 1	..	×	..	
„ sp. 2	..	×	..	
GASTROPODA.				
Promathilda **exilis** Healey.	×	×	×	cf. *P. ammoni* v. Wohr., *P. stuorensis* and *P. Antonii*, Kittl, Up. Trias; *Cerithium Martinianum* d'Orb., *Turritella Humberti* Martin, Lr. Lias.
„ cf. **exilis** Healey.	..	..	×	
„ **acedesta** Healey.	×	..	..	
„ sp. ind.	×	..	..	
„ (?) **contrita** Healey.	×	..	..	
Turritella (Mesalia) sp. ind.	×	..	..	
Loxonema (?) sp. ind.	×	..	..	

Scalaria (?) **exigua** Healey.	? ×	..	×	
Fibula (?) sp. ind.	×	..	..	
Mœrkeia (?) **burmensis** Heaely.	×	..	..	cf. *Cerithium morencyacum* Terq. and Piette, and *C. verrucosum* Terq., L. Lias, France.
Fusus (?) sp. ind.	×	×	..	

Lithological characters, Napeng area.

Over the greater part of the Napeng area the beds consist of yellow argillaceous shales and soft, sandy marls, sometimes passing into hardened grey calcareous shales, with here and there a band of hard blue limestone. One band of this latter rock is fairly persistent, and seems to occur at or quite close to the base of the formation. It is a dense, compact, splintery rock, usually crowded with fragments of shells, which show only on the weathered surface of the rock or in thin sections under the microscope. Sections cut from this limestone near Napeng and Loi-lam contain numerous minute foraminifera, including representatives of the families *Lituolidæ*, *Miliolidæ*, and *Textularidæ*, but as they can only be seen in this manner, their specific identity cannot be ascertained (Plate 15, fig. 2).

Kyaukkyan.

At Kyaukkyan (Loc. 11, D 3) the fossiliferous beds consist of yellow shales, resting upon a band of dark blue limestone similar to that described above. They are well exposed in the cuttings on the cart-road and on the railway, both of which pass through a notch in the great Kyaukkyan scarp at this point. The shales no doubt owe their preservation to the fact that they have been let down against the hard Plateau Limestone by a fault, already mentioned. They are exposed over a very small area, and do not extend for more than a few hundred yards to the north or south of the gap. At Hson-oi (Loc. 13, E 2) also, only a small patch of these beds is exposed, in a low cutting on the railway just before it crosses the cart-road above the railway bridge over the Námhsim river, and immediately beyond the cutting shown in Plate 21. Here the beds are harder and more calcareous than at Kyaukkyan, of a light grey colour, and some of the fossils have their shells preserved. Here also they are associated with a band of hard blue limestone, on the weathered surface of which corals, *Lophosmilia*, *Isastræa*, etc., are visible.

Hson-io.

Local character of fauna.

If we compare the lists of fossils given on previous pages of this Memoir with that shown in Table 11, it will be noticed that the number of new species which it has been found necessary to establish bears a much higher proportion to the total in the case of the Napeng beds than in that of any of the Palæozoic formations. The figures are given in Table 12.

TABLE 12.

FORMATION.	Total No. of species.	New species.	Percentage of new species.
Naungkangyi . . .	47	19	40·5
Namhsim . . .	41	7	17·0
Zebingyi	20	3	15·0
Padaukpin . . .	166	26	15·5
Wetwin	30	8	26·6
Permo-Carboniferous .	78	5	7·7
Napeng Beds . . .	81	43	53·0

Thus, of the 81 species described from the Napeng beds 43, or more than half, are new, while of the rest not more than three have been identified with forms occurring elsewhere, and six can only be compared with species already known, the remainder being indeterminable. But even this statement does not completely express the peculiar nature of this fauna. In describing it Miss Healey has found it necessary to establish two new families, the *Burmesiidæ* and the *Dattidæ*, and to refer to them three new genera, *Burmesia* and *Prolaria* to the former, and *Datta* to the latter. From these facts alone it is evident that, in the interval between the deposition of the Permo-Carboniferous limestones and that of the Napeng beds, great changes in the relations of sea and land must have occurred, resulting in the comparative isolation of the basin of which the Shan sea at this time formed a part.

Isolation of sea basin.

How far this basin extended to the north and south is not yet known. In Yunnan, Mr. Coggin Brown has found beds containing some of the peculiar Napeng fossils, including *Burmesia*, *Palæoneilo*, etc., resting, not directly upon the Carboniferous limestone, as in the Shan States, but upon a series of red sandstones and shales with beds of coal and salt which he considers to be of Permo-Triassic age. To the south it is interesting to find that one of the characteristic Napeng species, *Modiolopsis gonoides*, has been identified by Miss Healey with a fossil, doubtfully described as *Pleurophorus elongatus* Moore by Mr. E. T. Newton,[1] which is found in some soft, light fawn coloured sandstones,

Extension to Yunnan.

Malay Peninsula.

[1] Marine Triassic Lamellibranchs discovered in the Malay Peninsula; *Proc. Malac. Soc. London*, Vol. IV, p. 130.

a description that would apply to portions of the Napeng beds, discovered by Mr. H. F. Bellamy on the Lipis river in the Malay Peninsula. These beds, which also contain several *Myophorias* as well as *Chlamys valoniensis*, a characteristic Rhætic fossil, have been referred by Mr. Newton to the uppermost Trias or Rhætic; and it should be noticed that the composition of the fauna, consisting as it does entirely of lamellibranchs, is similar to that of the Napeng shales. Further to the south-east again, in Sumatra, some shaly limestones at Boekiet Kamdoeng and Loerah Tambang, on the west coast of the island, referred by Prof. Boettger to the Tertiary period,[1] have been shown by Miss Healey to contain at least three species (named respectively *Hemicardium myophoria*, *Cardita globularis*, and *Pinna Blanfordi* by Prof. Boettger), which resemble three of the Napeng forms, *Myophoria napengensis*, *Cardita singularis*, and *Pinna* cf. *Blanfordi* so closely that Prof. Boettger himself has agreed that the Sumatra beds must now be relegated to the Rhætic. In these beds also the great majority of the fossils are lamellibranchs. Thus it appears that the equivalents of the Napeng beds had a fairly wide distribution in the Eastern seas of the Rhætic period, but that in each case the fauna possessed a distinctively local character.

Sumatra.

It is perhaps hardly possible that a more striking instance could be found of the difficulty that exists in determining the exact age of a formation, when the only palæontological evidence at hand consists of the casts of mollusca, and in the absence of clear stratigraphical evidence, than this reference of beds really belonging to one and the same horizon, on the one side to the Devonian, as in the Shan States, and on the other to the Tertiary, as in Sumatra.

Equivalents in the Himalaya.

No trace of the peculiar fauna of the Napeng beds has yet been met with in the Himalaya. The rocks in that area overlying the Trias of Spiti and Kumaon, referred by Dr. Diener and others to the Rhætic period,[2] comprise the Para Limestone of Stoliczka,[3] corresponding with the Dachsteinkalk of the Eastern Alps, and containing large numbers of *Megalodon* and *Dicerocardium*, but very

[1] Die Tertiarformation von Sumatra und ihre Thierreste; *Palæontographica*, Suppl. II, Lief. 8, 9.

[2] Ladinic, Carnic, and Noric Faunæ of Spiti; *Pal. Ind.*, Ser. XV, Vol. V, Mem. No. 3, p. 156; Manual, Geology of India, 2nd Edn., p. 131.

[3] Geological sections across the Himalayan mountains; *Mem. Geol. Surv. Ind.*, Vol. V, p. 62; C. L. Grisbach, Geology of the Central Himalayas; *Ibid*, Vol. XXIII, p. 72.

few other fossils, and none that are specially characteristic of the 'Avicula contorta' zone. Further west, in Northern Afghanistan, a series of sandy beds with seams of coal was ascribed by Mr. C. L. Griesbach to the Rhætic,[1] but these beds have now been shown by Mr. Hayden to belong probably to a much higher horizon, and are considered by him to be the equivalents of the plant-bearing beds of Russian Turkestan, that is to say, deposited in a different basin from that of the Triassic beds of the Himalaya.[2] No strata that can with certainty be ascribed to the Rhætic stage have yet been found in that area.

Afghanistan.

Composition of the fauna.

The composition of the Napeng fauna also presents a strong contrast to that of the faunas that preceded it, with the exception of the Wetwin shales, in that, so far as it has been described, it consists almost entirely of lamellibranchs, with a few gastropods and a single brachiopod. But it should be remembered that we know practically nothing of the fauna that built up the limestones associated with the shales, except that it must have consisted to a great extent of brachiopoda and perhaps corals. Sections of the shells of brachiopods and gastropods, and of the spines of echinoderms are not uncommon in some of the limestones, and near Napeng I found the remains of a large sea-urchin in a soft marly layer, but in such a rotten condition that even the genus could not be made out. The similarity in composition between the fauna of these shales and those of Wetwin is significant, for it tends to confirm Mr. Cowper Reed's suggestion (*see above*, p. 254) that the peculiarity of the Wetwin fauna is due to bionomical surroundings; and indeed I have very little doubt that the two sets of beds were deposited under much the same conditions, repeated in the case of the Napeng shales after a prolonged interval of time. The recurrence in the Napeng beds of the American genus *Palæoneilo*, the most common fossil represented at Wetwin, is very suggestive in this connection.

Nawngping fossils.

The fossils collected from the ancient travertine deposit north of Nawngping (Loc. 12, D 3), mentioned on p. 287, have also been described by Miss Healey (*op. cit.*, pp. 87, 88), but none of them can be definitely

[1] Field notes from Afghanistan; *Records, Geol. Surv. Ind.*, Vol. XIX, Pt. 4, p. 243.
[2] Geology of Northern Afghanistan; *Memoirs, Geol. Surv. Ind.*, Vol. XXXIX, pt. 1, pp. 32, 79.

determined. They consist of a very small species of *Pteria* (*Avicula*), three very small gastropods referred to *Worthenia*, and perhaps species of *Loxonema* and *Acteonina*. All that can be said of them, as Miss Healey remarks, is that they "may very well be of Rhætic or lower Liassic age."

CHAPTER XII.

JURASSIC SYSTEM.

Namyau Series.

No evidence of unconformity.

Attention has already been drawn to the fact that there is no evidence of a stratigraphical break between the Napeng beds and those that succeed them, the absence of the former at the base of the overlying formation being accounted for by irregularities in the limestone floor upon which both were laid down. The change in the character of the deposits, which is well marked, seems to have been caused by the circumstance that, as the sea encroached upon the land, its shores in time extended up to the foot of the highlands, composed of ancient crystalline and other more or less siliceous rocks, which had surrounded the Devon-Carboniferous sea, and that the sediment resulting from the degradation of these older rocks was discharged directly into its waters and spread over the sea floor.

Conglomerates at base.

In the first instance, perhaps contemporaneously with the deposition of the Napeng beds, banks of coarse conglomerate, consisting of well rolled pebble of the Plateau Limestone and of the more ancient rocks, set in a sandy calcareous matrix, were laid down; but these are by no means continuous, and perhaps merely mark the position of beaches surrounding portions of the irregular limestone floor that remained for a time above water, and they are confined entirely to the base of the formation. Good examples of this conglomerate are to be seen on the Nám-Tu, a short distance above Ta-ti ferry (Loc. 7, F 2), on the trade route leading north from Hsipaw, and at Htengnoi lower down the river. As the sea deepened the material deposited became fine-grained, sandy or argillaceous, and a formation, consisting in the main of alternating beds of sandstones, shales and clays, with very subordinate carbonaceous layers, was gradually built up. It does not appear, however, that the water ever became very deep, for the sandstone layers are often beautifully ripple-marked. Examples of this structure may be seen in the deep cuttings on the railway above Hsipaw, where the hills come down to the banks of the Nám-Tu.

Lithological characters.

The whole series is distinguished by its colour, which is generally a dark red, often with a decided purplish tinge; but beds of grey, pepper and salt sandstones, and bands of yellow clay are sometimes interstratified, especially in the higher parts of the series.

Weathering.

The sandstones are, as a rule, soft and friable, and are only occasionally hard enough to be used as building stone; consequently the areas composed of these rocks are readily affected by denudation, and invariably consist of an intricate network of ridges and ravines with no marked uniformity in direction, the whole covered with dense forest, and almost trackless; the inhabitants being few and their villages and patches of cultivation only met with at long intervals.

Thickness.

Nothing definite can be said about the thickness of the formation, for the absence of continuous sections and of an upper limit, coupled with the intense disturbance of the beds, the prevalence of faults, and the enormous amount of denudation that the series has undergone, make it impossible to give even an approximate estimate, but it must amount to several thousand feet.

Limestone bands.

In the earlier stages of this epoch bands of limestone were formed at intervals, none of them more than a few feet thick, but very uniform in thickness and often persistent for several miles. They were perhaps accumulated at times when, for one reason or another, the supply of sandy or muddy sediment was cut off, and their absence from the upper portion of the series is an indication of the setting in of more uniform conditions as time went on. They are usually homogeneous in texture, very compact and fine-grained, but often argillaceous and abounding in fossils, passing into shelly limestones. Being easily weathered these bands form no conspicuous feature on the surface, and owing to the density of the forest they can only be traced at intervals, in the stream beds and on the paths, and the course of those shown on the map is therefore partly conjectural; but they indicate very clearly the direction of the prevailing strike of the formation, from N.N.E. to S.S.W., and the profound disturbance that the rocks have undergone, for they generally dip at high angles and are often vertical.

Distribution.

It is evident that this formation must have once covered a very much wider area than it does at present, but it has suffered so greatly from denudation

that it is now entirely removed from the western portion of the Shan plateau. No occurrence of it is known to the west of the Gokteik gorge, and to the east it makes its first appearance at the conflux of the Námhsim with the Nám-Tu near Bawgyô. To the north and south of Hsipaw it covers a very wide area, and it is well developed along the railway from that place towards Lashio, especially in the valley of the Námyau river, from which its name has been taken. The magnificent falls of Mánlong-Mán-sang on this river (see Frontispiece) between Se In and Mánhpwi stations, owe their existence to the more rapid erosion of the red beds as compared with that of the Plateau Limestone, against which the former are let down by a fault crossing the river below the falls. A study of the map will show that the boundary of the formation frequently coincides with a fault. And it is evidently to this circumstance,—that the red beds have been faulted down among the hard limestones,—that in most cases they owe their preservation from complete denudation; though here and there outlying patches may be found which are not protected by faults, as for instance on the plateau south of the cart-road, between Hsipaw and the Námpawng.

Mán-sang Falls.

Faulted boundaries.

To the east of Lashio there is another large area of these rocks, extending from the northern side of the Námpawng valley in a north-easterly direction to and beyond the Lashio coal-field on the Námyau. On the latter river these beds attracted the attention of Dr. Noetling, who refers to them as "red sandstones of undetermined age,"[1] but he was not aware of their extension to the north and south, and introduces a somewhat fanciful theory to account for their presence in the river valley (*op. cit.*, p. 102, *see ante*, p. 5). How much further they extend to the north is not yet known; but precisely similar beds have been found by Mr. Coggin Brown in Yunnan, overlying the Napeng beds discovered by him in that country, and v. Loczy has described strata of the same character and age, occurring in Sze-chuan and other parts of China.[2]

Eastern area.

Probable equivalents in China.

[1] Coal Fields in the Northern Shan States; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, pp. 103, 105.

[2] Reise des Grafen Bela Szechenyi, Vol. I, pp. 439, 671.

Outliers.

No beds belonging to the Námyau series have been met with in the hilly country surrounding Loi Ling, but an outlier of red sandstones was noticed to the east of the Námlawng, near the small village of Mán-pung in South Hsenwi (I 3); and I have already alluded to the occurrence of similar beds at Kehsi Mansam, where a small patch has been preserved by faulting (*see above*, p. 259).

Extension to Southern Shan States.

In the Southern Shan States Mr. Middlemiss has described,[1] under the name of the "Purple Sandstone Zone," a series of beds which I have no hesitation in considering to be the equivalents of the Námyau series of the Northern States—an opinion in which Mr. Middlemiss concurred after comparing his specimens with those collected by Mr. Datta and myself. The mode of occurrence of these beds is precisely similar, broad bands of them appearing—

"to have been let down by faulting among the limestone zone, or to have been tucked in along certain lines and axes of reversed folds and faults."

Interbedded conglomerates and coal.

The only difference is the presence, in Mr. Middlemiss' area, of interbedded conglomerates, of considerable coarseness and thickness, apparently at several different horizons; and of thin seams of coal. From the occurrence of this mineral, Mr. Middlemiss was inclined to consider that the series was of Tertiary age, as coal measures of this age were previously known to occur in the Southern Shan States,[2] and to be contemporaneous with the very similar beds of Kasauli and Murree in the N. W. Himalaya; but at that time no fossil evidence was forthcoming to give a clue to the age of the series, and as there was no reason to suppose that they were very different in age from the underlying Napeng beds, they were referred doubtfully, with the latter, to the Devonian.

Fossil localities.

The fossils collected from this formation have been obtained almost entirely from the bands of limestone described above. In the course of my traverse of 1899-1900, I came upon a few fragmentary fossils in the red sandstones near Se-Eng (Se-in) railway station (G 2), between Hsipaw and Lashio, but on revisiting the spot later on I found that, the railway being then under construction, the outcrop had been

[1] General Report, *Geol. Surv. Ind.*, 1899-1900, p. 143.
[2] E. J. Jones, Notes on Upper Burma; *Records, Geol. Surv. Ind.*, Vol. XX, Pt. 4, p. 177.

cut away, and I could not identify the fossiliferous bed. Subsequently, however, during the field-season of 1901-1902, Mr. Datta discovered a number of brachiopods, chiefly *Terebratula* and *Rhynchonella*, in one of the limestone bands on the left bank of the Nám-Tu opposite Bawgyô (**F** 2), and a good collection was also made from a band of shelly limestone exposed in a railway cutting about two miles beyond Se-In[1] (Loc. 8, **G** 2). Later on, when the limestone bands to the north of Hsipaw were searched, a very fair collection of fossils was obtained at the following localities:—Na-kyeh (Loc. 4, **G** 1); Nahawk and Namhathai (Locs. 5 and 6, **F** 1); and Ta-ti (Loc. 7, **F** 2). The brachiopods from these places have been submitted to Mr. S. S. Buckman for description;[2] but unfortunately, the results of his examination of the collections are not yet ready for publication, and I am therefore not in a position to give a complete list of the fossils. The general conclusion, kindly communicated to me by Mr. Buckman, is that the Námyau beds are probably equivalent to the Bathonian (Bradford Clay and Cornbrash) of England, though it is quite possible that more than one horizon is represented. Much more field work, however, is necessary before the relations of the different bands to each other can be determined; and it will probably be found that they do not all belong to a single horizon. But the absence of limestone bands in the upper portion of the series, and of any rock whatever overlying the red sandstones, will render it impossible, I fear, to determine the upper limits of the formation.

Age.

It is noteworthy that in the whole collection from these beds there is not a single Ammonite or other Cephalopod, though at this period they were common enough in the Central Himalayan area and in Cutch. One

Absence of Cephalopoda.

[1] It may be interesting to collectors to record the circumstances of this latter find, as it affords a hint for the treatment of such limestones as these, where the fossils are seen only on the weathered surface, and cannot be extracted without difficulty, if at all. I found a Shan coolie in the act of breaking up a heap of limestone blocks into ballast, and to my surprise, at nearly every blow of his hammer a whole *Terebratula* or other fossil fell out like a kernel from a nut; and this after I had spent hours in trying to extract a recognisable fossil from the rock! Examining his method more closely, I found that the material on which he was working had been partially burnt in an adjoining lime-kiln, and that the expansion of the rock, due to the heat, had evidently loosened the fossils from the matrix. Taking the hint, I roasted a number of blocks of the limestone in a large open fire, and was rewarded with a fair number of specimens, but it was evident that it required the concentrated heat of a kiln to make the experiment a complete success.

[2] A few fossils were also obtained from these beds on the left bank of the Nám-Tu at Tong-ang (Loc. 9, **F** 3) and at the foot of the Pongwo scarp near Namhsawm (Loc. 10, **E** 3) about 3 miles south-east of Pangsam.

form of *Rhynchonella* is considered by Mr. Buckman to resemble *R. asymmetrica* Kitchin, and a *Terebratula* to be comparable with *T. dhosaënsis* Kitchin, both from the Chari (=Callovian) group in Cutch; but neither he himself nor Dr. Kitchin consider that there is identity in either case. All that can be said at present, therefore, is that the Namyau beds are certainly in part of Jurassic age, and that they were probably of a continental character, and were deposited along the shores of a shallow sea extending northwards into China. The presence of red beds throughout the series is perhaps in favour of this view. How far they may extend to the south, beyond the Southern Shan States, is not yet known.

Character of deposits.

CHAPTER XIII.

TERTIARY.

Freshwater Beds.

Close of marine deposition.

With the deposition of the red sandstone series the long succession of marine formations which we have passed in review, extending from lower Ordovician times to the Jurassic period, comes to an end. No trace of the marine Cretaceous or of the Eocene, Oligocene, and Miocene formations which are so well developed and widespread in the plains of Lower and Upper Burma has been found on the uplands, and it is evident that, when the Tertiary sea extended over what is now the valley of the Irrawaddy, the Shan plateau had already been raised above its waters. But the upheaval that resulted in this total cessation of deposition was merely a local development of events that affected a very large portion of the earth's surface at this period. For a long time before this, signs had not been wanting that the ancient Gondwana continent was being broken up. On the west coast of India the Jurassic sea had penetrated nearly as far to the south as the latitude of Bombay; and on the east the Bay of Bengal, which must have appeared as a depression in the old continent at an even earlier date, for Triassic rocks are known to occur on its shores in the Arakan Yoma, had extended its waters in the Cretaceous period as far to the north as the borders of Assam. The elevation of the Shan plateau is then but a local manifestation of the great orogenic movements that advanced upon the Peninsula of India from three different directions; resulting on the west in the upheaval of the Suleiman ranges, on the north in that of the Himalaya, and on the east in that of the Assam and Arakan ranges. From this time on, therefore, the history of the area we are dealing with is one of degradation and modification of the superficial features; and it was not until the present configuration of hill and valley had been blocked out that the deposition, at any rate of beds that have endured to the present day, again set in.

Lithological characters.

The rocks which have been ascribed to the Tertiary period in these hills consist of silts and soft sand-rock, – so slightly consolidated that they break down into a soft mud when immersed in water,—pebble and boulder

beds, and seams of brown, lignitic coal, which last are in general the most substantial rocks seen in the few outcrops that occur, and to which the formation owes such importance as it possesses. They are found in detached areas occupying the present river valleys, and it is significant that they are confined to the portions of the plateau surrounding the high ground culminating in the lofty peak of Loi Ling, the highest point in the States. These detached basins, in fact, seem to have formed an assemblage of lakes similar to that of the English Lake District, and were either silted up entirely, or were perhaps drained by the deepening and cutting back of the channels in the limestone through which the rivers in every case now find their exit.

Old lake basins.

The economic importance of this formation, due to the presence of the coal seams, has led to the devotion of a considerable amount of attention to it, and full accounts of each basin, the mode of occurrence of the beds and the economic value of the fuel they contain, have appeared in the *Records* of the Geological Survey.[1] The areas in which they have hitherto been found are six in number :—

Distribution.

(i) In the upper part of the Námyau valley, beyond the limits of the map, there is a small patch of these rocks, surrounding the village of Mongyaw (Lat. 23° 2′, Long. 98° 9′), but little is known about them. I searched for coal in them in 1900, but without success, nor did the inhabitants seem to be aware of any outcrops. In any case they cover a very small area. This patch is separated from the Lashio coal-field by a broad band of the Námyau sandstones, which crosses the valley from south-west to north-east between Mongyaw and Mongyang, and through which the river flows in a deep gorge.

(ii) The Lashio coal-field. This basin extends along the Námyau valley from Mongyang westwards to Hsunkwé, a few miles north of Lashio, and is about 15 miles in length, with an average breadth of 4 miles. The river runs along the southern boundary of the field, which is all that

1 F. Noetling, Coal-Fields in the Northern Shan States; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 99: T. D. La Touche and R. R. Simpson, The Lashio Coal-Field; *Ibid*, Vol. XXXIII, Pt. 2, p. 117: R. R. Simpson, The Namma, Man-sang, and Man-se-le Coal-Fields; *Ibid*, p. 125: P. N. Datta, MS. Report, 1903-04.

appears on the map attached to this Memoir, and leaves it just below Hsunkwé by a narrow, though not deep gorge in the Plateau Limestone. The floor of the valley consists partly of the limestone and partly of the Námyau sandstones, and not only do the silts cross the boundary between the two formations without interruption, but they also traverse in the same way a strong fault, which crosses the river close to the ford north of Lashio, and is marked by a line of hot springs. The beds consist of sandy silts and soft sand-rock with very subordinate pebble bands and an occasional layer of harder ferruginous sandstone; but even these are only indurated near the surface, where the iron oxide in them is concentrated. They form low rolling hills covered with grass and very scattered tree jungle, traversed by numerous sluggish watercourses. Outcrops are only to be seen along the course of the river, the northern boundary being entirely concealed by rainwash from the surrounding hills. The general dip of the strata exposed along the river is to the north, and since the coal seams are confined to the lower portion of the formation, they are only to be seen in the river bed or close to it in a few of the deeper ravines.

Lithological characters.

Position of coal seams.

(iii) The Nammá field. This is perhaps the most important of the Tertiary basins, as it contains the most promising coal seams, though the inferiority of the coal, and the distance of the field from the railway, make it unlikely that it will ever be worth while to exploit the mineral. The field extends along the north bank of the Námpawng, from its junction with the Nammá near the large village of the same name (**H** 2), for a distance of about 15 miles, with an average width of 3¼ miles. This area differs from that of Lashio in being covered for the most part with dense forest, which rendered the task of prospecting very difficult. The beds also exhibit a greater variety than in the Lashio field, the grey sandy silts being subordinate, while there is a

Lithological characters.

greater preponderance of clays, generally of a yellow colour; but some, in the neighbourhood of Mán-Sé (Loc. 2, **H** 1), are pure white, resembling kaolin, and may perhaps prove to be of economic value as pottery clays. Beds of conglomerate are also more numerous, made up of pebbles and boulders of quartz and crystalline rocks derived from the hills to the east. As in the Lashio field the coal seams appear to be confined to the lower portion of the group, but there is much more variety in the dips, and the outcrop of the seams is not confined to the bed of the rivers. The general dip is low, about 20 degrees on an average, and is directed towards the north-west at the western end of the field and to the north-east at the opposite end (Plate 16); but there are considerable local variations, due perhaps to the underground denudation of the limestone floor. The northern boundary is obscure, and may be partly faulted, but the appearance of faulting may be due to the same cause as the unevenness of the dips. The southern boundary is a natural one.

Conglomerates.

Position of coal seams.

(iv) Below the Nammá field the river races through a deep narrow gorge in the limestone to its junction with the Námyau at Se-In, but about three miles below the main area it passes through a small oval basin of the Tertiary rocks extending for about 5 miles along its banks and about half a mile broad. No outcrops of coal were found in this outlier, and the rocks exposed have not been described. It may have been connected at one time with the Nammá field, but it is quite as likely to have been an independent basin of deposition.

(v) The Mán-sang field. This basin is situated in the State of South Hsenwi, about 7 miles to the west of Möng Yai, the capital of the State, and about 16 miles to the south-east of the Nammá field (**H** 3). It covers an area of about 13 square miles, but the southern and south-eastern boundaries are very ill defined, being concealed by recent clays. The rocks are similar to those of the Lashio

Lithological characters.

field, consisting of sandy silts, white, yellow or grey in colour, and the dips are usually at low angles, except along the northern boundary, where they amount to from 30 to 50 degrees, and point to some local disturbance at the edge of the basin. Numerous seams of coal occur, but most of them are thin and of no economic value.

Volcanic outburst.

The chief interest of this old lake basin lies in the fact that its shores witnessed the first manifestation of volcanic activity that can be shown to have taken place anywhere in the Shan States, since the Cambrian epoch at least; for throughout the whole sequence of fossiliferous rock that has been described in the foregoing pages no trace of such activity has hitherto been detected. Till now the orogenic movements which caused breaks in the sequence, even those which occurred during the Triassic period, appear to have been so superficial or local in character that they did not affect the deep-seated sources of igneous action; but the later movements that resulted in the extraordinary series of faults by which the whole of the plateau is intersected seem, in this one spot, to have opened a way to the dormant energies lying below. In the Irrawaddy valley and in south-western Yunnan the exhibition of these forces resulted in the outpouring of the lava and ash beds that built up the great volcanoes of Popa and Hawshuenshan respectively, but in the Northern Shan States the display of volcanic activity was of a very feeble character.

Basaltic dykes.

While engaged on the survey of the Mán-sang field in 1905, Mr. Simpson noticed the occurrence, along its northern edge, of a number of basaltic or doleritic dykes, some of which possessed a distinctly amygdaloid structure (*op. cit.*, p. 145). I had also met with the same rocks during a rapid traverse made across the north-west edge of the field earlier in the same year, but had been unable to determine whether the rock was intrusive or not in the silts, or to find any centre of eruption. Later on, however, while surveying the country about Möng-Yai, I was struck with the appearance of a conical hill named Loi Han Hun, rising to about 700 feet above the plain, some 6 miles to the north-west of the capital, and on examining it found that, while the lower part was composed of the Tertiary silts, the upper part was a dome-shaped mass of columnar basalt, with dykes

Focus of eruption.

of the same material radiating in all directions from it, but most highly developed towards the west and north-west, where there may be another focus of eruption. This hill appears in the centre of the view of Loi Ling (Plate 1). It is from these dykes that the boulders of dolerite, mentioned by Mr. Simpson, which choke every stream bed in the neighbourhood, have been derived. No amygdaloid rocks were seen on Loi Han Hun itself, but their occurrence in the vicinity seems to show that some lava actually flowed from it. Otherwise the energy of the volcano appears to have been just sufficient to extrude the dome of basalt now forming the upper part of the hill and to fill the fissures surrounding it, no traces of a true cone built up of ashes or tuffs being visible.

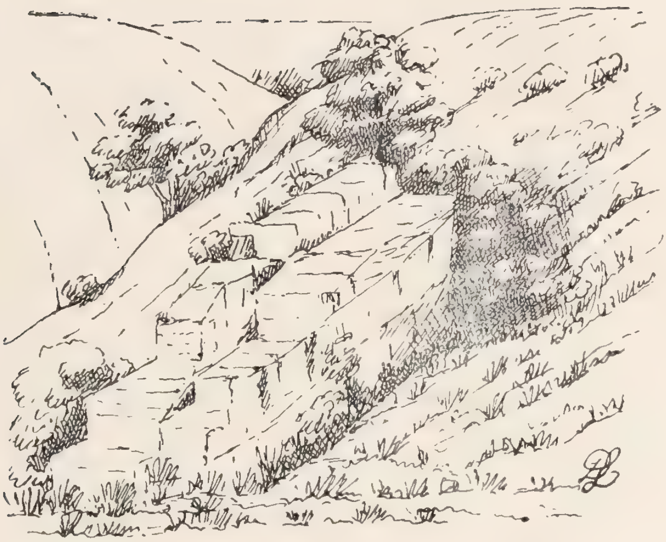
Petrographical characters.

The rock of which the dome is composed is a dense basalt, almost black in colour with a greenish tinge, consisting of an aggregate of minute lath-shaped crystals of plagioclase felspar and minute granules of augite, in which large crystals of plagioclase with zonal inclusions of the ground mass, much magnetite, and granular crystals of olivine are disseminated.[1] (Plate 7, fig. 2.)

(vi) Mán-se-lé field. The last of the Tertiary basins to be described covers a very wide area, but only a small portion of it, the Mán-se-lé coal-field of Mr. Simpson (*op. cit.*, p. 152), is known to contain coal seams. This area is situated on the east side of Loi Ling, covering the greater part of the valley extending southwards from the base of the hill to the Nám-Pat, an area of about 36 square miles (**J** 2). Beds of coarse sandstone are more common than in the Lashio field, but otherwise the rocks are similar. Several seams of coal were met with, but none of them appear to be of economic value, at any rate for many years to come On the southern boundary of the field, near Mánkün, is an interesting exposure of white kaolin-like clay, similar to that at Mán-Sé in the Nammá field. At this place the clay appears to have filled a fissure in the limestone floor of the basin

White-clay.

[1] La Touche, A Volcanic Outburst of late Tertiary age, etc.; *Records, Geol. Surv. Ind.*, Vol. XXXVI, Pt. 1, p. 40.



From a sketch by the author.

FIG. 9. 'Dyke' of white Tertiary clay in Plateau Limestone, near Man-kün.

for it now resembles a dyke with vertical walls on either side, projecting from the hill slope, the limestone which originally enclosed it having disappeared by solution (Fig. 9).

Fossils—Lashio coal-field.

The palæontological evidence available for determining the period to which these beds belong is somewhat meagre and unsatisfactory, but such as it is, it indicates an extremely late Tertiary, or perhaps even Pleistocene age. The fossils that do occur are all shells of gastropods of fresh-water types, and the leaves of plants. In the Lashio basin they have as yet been found only at one spot, in a seam of coal and the clays associated with it, exposed on the right bank of the Námyau immediately above a sharp bend in the river opposite the village of Hko-hkam (Loc. 1, **H** 1). This locality is mentioned by Dr. Noetling (*Records, G. S. I.*, Vol. XXIV, Pt. 2, pp. 106, 114), who says:—

"The only species I could distinguish belonged apparently to the genus *Planorbis*. There were also fragment of another big gastropod, which could not be determined."

This latter shell has since been examined by Mr. G. H. Tipper, of the Geological Survey, who says that it also is a *Planorbis*, and that it seems closely to resemble an upper Miocene form. The appearance of these shells is extremely recent, the original shell-substance being perfectly intact, though most of them are smashed to atoms, while in some cases even the colours are preserved.

Fossils—Namma coal-field.

In the Nammá field Mr. Simpson found large numbers of gastropods in some of the clay bands associated with the coal seams, especially in some of the ravines among the low hills on the west of Nammá village (Loc. 3, **H** 2). Some of the shells are in a better state of preservation than those mentioned above, but still not sufficiently so to enable the species to be identified. Among them my colleague Mr. Tipper, to whom I am indebted for the following notes, has made out three genera :—

"*Melanopsis* sp. The shell referred to this genus is generally quite well preserved. In general shape and ornamentation it resembles *M. Lörentheyi*, figured by Andrussow (Beitr. zur kenntniss des Kaspichen Neogen; *Mem. Com. Geol. St. Petersb.*, N. S., Livr. 40, figs. 16-20) from beds of Pontian age. It differs from this in the extraordinary thickening of the inner lip of the aperture, this thickening forming a callous growth over half of the last whorl."

"*Vivipara sp.*, characterised by three distinct smooth, rounded keels. On the last whorl a fourth keel, much less prominent, can be distinguished. This species differs from the present day keeled *Vivipara* quite distinctly and seems to resemble very closely *V. Pauli* Brusina, from the Paludinen-Schichten of Europe."

"*Hydrobia* sp. A small shell may be referred to this genus."

"Other genera are represented, but have not been identified chiefly on account of the difficulty of clearing them from the matrix."

In this basin the white kaolin-like clays exposed in a low hill about half a mile north of Mán-Sé (Loc. 2, **H** 1) contain, besides small gastropod shells, numerous impressions of dictyledonous leaves and of grasses; but none of these have yet been determined. Leaf impressions are also found in the outcrop of a similar clay mentioned on page 314 as occurring at Mankün (**I** 2) in the Mán-se-lé basin.

Age.

Until the species of some of the shells found in these beds is determined their exact horizon must remain doubtful, for all the genera mentioned range from the Miocene or even older periods, to Recent. The amount of disturbance that the beds have undergone, which cannot all be

attributed to underground denudation of the rocks on which they lie (since in the Lashio coal-field the silts resting on the limestone and on the Námyau sandstones are equally inclined), shows that the period of deposition was anterior to the cessation of orogenic activity in this region, and that the basins in which the silts were accumulated may have resulted from a 'warping' of the surface, already carved into its present outlines. The volcanic outburst in the Mánsang basin, which undoubtedly took place after some of the silts had been deposited, is also an indication that these movements had not ceased at this period, and if this eruption was contemporaneous with that of Hawshuenshan near Tengyueh in Yunnan, it may very well be of Pleistocene age. For v. Loczy has shown[1] that Hawshuenshan was active at the time when the alluvium of the Tengyueh basin, which he thinks was then occupied by a lake, was being deposited. For my own part, I am inclined to think that these lignite-bearing silts of the Shan States should be correlated approximately with the Pleistocene gravels of the Narbada, Tapti, and Godavari rivers in the Indian peninsula which, as Mr. Vredenburg has shown, were accumulated in basins due to 'warping' of the surface in Pleistocene times.[2]

I am informed by my colleague Mr. Coggin Brown that in Yunnan strata of precisely the same character as those now under description are of common occurrence in the valleys, and that they also contain lignite. The towns of that country are frequently built upon them, and they have all the appearance of sediments filling old lake basins. He also informs me that he has found in them a species of *Bythinia* identical with one which is still living in the Erh-hai lake at Ta-li-fu. In the Southern Shan States also Mr. E. J. Jones has described (*Records G. S. I.*, Vol. XX, Pt. 4, p. 1907) a bed of lignite, near the shores of the Nyaungwé lake, which he considers to be imbedded in an old lake-deposit similar to that which is now being accumulated not far off in the present lake.

Condition of specimens.

It is to be hoped that further collections will be made from these interesting beds, and that some more definite pronouncement as to their age may be possible in the future; but the rocks and the fossils contained in them are so friable that it is difficult to preserve them. The ground is everywhere saturated with water, and so soon as the

1 Reise des Grafen Bela Szechenyi in Ostasien, Vol. I, p. 772.

2 Pleistocene movements in India: *Records, Geol. Sur. Ind.*, Vol. XXXIII, Pt. 1, p. 13.

clays are exposed to the air and become dry they crumble into dust, while the lignite splits into cubical fragments like a piece of rotten wood. A collector, therefore, should be equipped with some means of hardening the specimens on the spot, either by soaking them in varnish or otherwise.[1]

[1] Mr. Tipper tells me that he has found the following method of hardening these fossils very successful. The specimen, cleaned as far as possible from adhering matrix, is first soaked in a solution of silicate of soda, 'water glass,' and then in one of chloride of calcium; it is then thoroughly dried, and painted over either with Canada balsam or with hard white copal varnish.

CHAPTER XIV.

SUB-RECENT AND RECENT DEPOSITS.

(1) Sub-recent : Old River terraces.

Mode of occurrence.

The remains of deposits that can truly be described as sub-recent, that is to say, accumulated under conditions similar to those now in existence, but actually undergoing denudation, are not of great extent in the Shan hills. The few ancient river terraces that occur are only to be met with in the valleys of those rivers that traverse the rocks older than the Plateau Limestone, in the northern portion of the States, for the limestone is so readily soluble that it is quite an uncommon occurrence to find even a talus of fragments of this rock at the foot of a scarp ; and pebble beaches in the streams that flow over it are practically non-existent.

Mogôk valley.

Of the old river terraces that do exist the most important are the ruby gravels of the Mogôk valley and the surrounding district; the tourmaline gravels in the Möng Lông sub-State ; and the terraces in the valley of the Nám-Tu. All these deposits have been already described in various papers. The alluvial gravels of Mogôk have been dealt with by Prof. Judd and Mr. Barrington Brown in their work on the Rubies of Burma.[1] Two stages of alluvium are mentioned, the one a recent deposit forming the floor of the valley, and the other an old river gravel deposited at a higher elevation with its base on a level with, or slightly above, the surface of the present alluvium. There is some reason to suppose that a good deal of the alluvial flats, which are now being excavated and washed for rubies, belong to a condition of things that has now passed away, and must therefore be considered as sub-recent ; for during the process of washing the gravel for gems considerable numbers of stone implements and of bronze fish-hooks, the latter probably of Chinese manufacture, are obtained in places well removed from the actual river course, and in the lower part of the deposit which contains the rubies.

Old lake basin.

[1] *Phil. Trans. Roy. Soc., London,* Vol. 187A, p. 164.

This seems to show that at one time the floor of the valley was occupied by a lake, since the present insignificant stream carries no fish that could be caught with hooks of the size found, and the manner in which these and the stone implements occur suggests their having been dropped from boats, which there is now not water enough to float. The narrow and precipitous gorge through which the stream now escapes from the valley also suggests that at one time a lake lay above the exit; and it is probable that the rocky floor underlying the ruby gravels lies below the lip of the falls, and therefore forms a true rock-basin.

Ruby gravel. Namhsu-hka.

Another old terrace deposit in the same neighbourhood has been described by Dr. Noetling.[1] This is situated in the valley of the Nám-pai, about 15 miles to the west of Möng Lông (Mainglôn) and at the junction of a small stream, the Námhsu-hká (Namseka), with the main river (C 1). The ruby-bearing gravel here seems to be the remains of an old terrace deposited by the Mogôk river, which joins the Nám-pai at this point, at a time when the valley had not been cut down to its present level; for the rubies contained in it must have been brought down from the Mogôk valley, the only direction in which the crystalline limestone, which constitutes the matrix of the gems, has been found.

Tourmaline gravels of Möng Long.

The tourmaline gravels of Möng Lông were also described by Dr. Noetling in the same part of the *Records*.[2] They are situated higher up in the valley of the same river, the Nám-pai, and are found along both sides of it, extending for about five miles eastwards from a point about two miles north of the town of Möng Lông. The boulder and gravel deposits forming the terraces reach, according to Dr. Noetling, to a height of about 200 feet above the river, and consist mainly of quartz pebbles and boulders; evidently an old fan-talus derived from the hills to the north, which are composed of gneisses with bands of tourmaline granite, traversed by numerous quartz veins. The pebbles of blue shale or schist, also mentioned by Dr. Noetling, probably come from the hills to the south. It does not seem possible that such coarse deposits as these could have been accumulated on the bed of a lake, as he suggests, and the red clay which he speaks of as overlying the

[1] The Namseka Ruby Mine; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 119.
[2] The Tourmaline Mines in the Mainglôn State; *Ibid*, p. 125.

gravels has none of the appearance of a lacustrine deposit, but is the same that covers both valley and hill slope everywhere in the neighbourhood.

Nám-Tu valley.

Change in course of river.

I have already given an account of the old river terraces in the valley of the Nám-Tu near Hsipaw in the pages of the *Records*,[1] and have shown how they were in all probability responsible for the peculiar course now taken by the river above the town. According to this hypothesis the waters of the river, issuing from the deep gorge above Ta-ti ferry, and carrying an immense quantity of debris derived from the old slaty and schistose rocks on its left bank, spread out this material over the broad valley, excavated in the soft red Námyau sandstones and shales, in which the large towns of Hsipaw and Bawgyô are situated. At this time the narrow valley below the junction of the Námhsim with the Nám-Tu was perhaps not cut down to its present depth; and the boulder deposits accumulated and blocked up the bed of the river, until it rose to a sufficient height at the point where it debouched from the gorge at Ta-ti to find a way across the spur to the south-east, and so into the Nammá, 12 miles above Hsipaw. The remains of old terraces are also to be seen below the mouth of the Námhsim, especially at Htengnoi (**F** 3), where they reach an elevation of more than 100 feet above the present river level.

Period at which terraces were formed.

There is no direct evidence indicating the period at which the terraces were formed, except that, as they are now undergoing denudation, they were deposited under conditions that no longer exist. I have suggested, in a lecture delivered before the Asiatic Society of Bengal,[2] that in the Himalaya similar terraces may be attributed to the latter part of the Glacial period, when a more rigorous climate deprived the hills of their covering of vegetation, and thus enhanced the action of atmospheric denudation to such an extent that the valleys were choked with the debris carried into them. And although there is no direct evidence of the prevalence of glacial conditions among the hills of the Shan States, yet the high ground to the north of the plateau, reaching to altitudes of over 7,000

No evidence of glacial action.

[1] Recent Changes in the Course of the Nam-Tu River, *Ibid*, Vol. XXXIII, Pt. 1, p. 46.
[2] Relics of the Great Ice Age in the Plains of India; *Geol. Mag.* Dec. V, Vol. VII, p. 193.

feet, and about Loi Ling (8,771 feet), must have been affected in the same manner, though in a minor degree, by the refrigeration of the climate, with a similar result.

(2) Recent deposits.

Classification.

There are four categories of recent deposits that deserve mention, (*a*) the red clays of the limestone area, (*b*) travertine or calcareous tufa, (*c*) river alluvium, and (*d*) the peaty deposits of the uplands.

(*a*) *Surface Clays.*

Lithological characters.

One of the most striking features of the plateau country is the universal mantle of red clay which is spread over the limestone. When one ascends even the smallest elevation above the cultivated straths that border the streams, red is the prevailing colour that meets the eye, wherever the soil is exposed, and it certainly adds much to the picturesque character of the scenery. The colour is a bright Indian red, sometimes with a slightly orange tint when dry, but becoming much darker when wet. On the open plateau the clay contains little or no sandy matter, and is of a stiff, tenacious nature, very slippery when wet with rain.[1] It is usually filled with pisolitic nodules of iron oxide, ranging from the size of a pea to that of a hazel nut, resembling the nodules of which some varieties of laterite are built up. In fact it is not improbable that the red clay owes its growth to a process similar to that to which the origin of laterite is generally attributed, the decomposition of the underlying rock; but in this case the resulting product is less consolidated, owing perhaps to the absence of siliceous matter from the limestone. It corresponds rather to the 'Terra Rossa' of south-east Europe,[2] where it is largely developed in the limestone tracts (*Karstgebiete*) of Istria and Dalmatia:

'Terra Rossa.'

1 The stiffness of this clay has a peculiar effect upon the Shan roads, which I do not remember to have noticed elsewhere. During the rainy season the feet of the bullocks, which are commonly used as pack animals, poach the clay into a series of parallel trenches running transversely across the roads, leaving solid bars between them which remain throughout the dry season and form a most uncomfortable road to travel over. It resembles nothing so much as an abandoned railway, from which the sleepers have been recently removed.

2 Walther von Knebel, Höhlenkunde mit Berücksichtigung der Karstphänomene *Die Wissenschaft*, Heft 15, p. 29.

where, however, it is usually confined to hollows in the surface and to caverns.

Thickness.

The thickness of the red clay sometimes assumes large proportions, as may be seen in many of the cuttings along the railway, where it is seen to rest upon a deeply eroded surface of the limestone, often filling 'pipes' in the latter. Many of these cuttings show that the clay may be 20, 30, or even more feet in depth. If the whole of this were to represent the residue remaining from the solution of the limestone, it would mean the removal of an enormous mass of rock, for the proportion of insoluble matter contained in the limestone is very minute; but though much of it must be attributed to this origin, its growth must have been largely supplemented by the denudation of the bands of clay that are interstratified with the limestone.

Origin.

Gen. Collett's theory.

An account of the red clay, and of some of the phenomena connected with it, was communicated to the Asiatic Society of Bengal by Brig.-Gen. H. Collett in 1888,[1] and should be mentioned here. Gen. Collett thinks that the red clay once covered the whole of the plateau to a depth of several hundred feet; that it may have been of marine or lacustrine origin; and that the funnel shaped hollows, to which I have already alluded (pp. 23, 194), are due to the washing down of the clay through subterranean channels in the limestone beneath. But if the sides of the hollows are examined, it will be found that they are really composed of solid limestone, though the rock is often masked by a thick covering of the clay. Moreover, the average thickness of the clay is no greater in the valleys than it is upon the crests of the highest ridges, as it should be on Gen. Collett's hypothesis. And in addition to this, there is no evidence whatever that within recent times the whole of the plateau has been covered by the waters of an ocean or large lake, in which the clay might have been deposited.

Character of soil.

The red clay forms a somewhat sterile soil, so far as the production of cereals is concerned, and is particularly unfavourable to the growth of wheat, all experiments in this direction having met with failure. It is largely cultivated, however, under the Shan system known as Hai

[1] Some features in the Geological Structure of the Myelat District of the Southern Shan States; *Journ. As. Soc. Bengal.*, Vol. LVII, Pt. 2, p. 384.

(*Burm.* Taung ya), which corresponds to the 'jhuming' of the hill tribes of Assam. Under this system a certain area is cleared of jungle, which is burnt on the spot when dry, and crops, chiefly rice and millet, are grown for three, or perhaps four years in succession, when the land becomes exhausted, mainly by the washing away of its fertile constituents during the rains. After the lapse of several years, when the ground is again covered with scrub jungle, the process is repeated; and it does not appear to have such evil results on the erosion of the soil as might be supposed, for in the course of a year or so the surface is protected by a covering of coarse grass. The sterility of the soil may be in some measure due to the absence of lime. For though it is derived in great part from the decomposition of the limestone beneath it, analysis shows that it contains no trace of lime, even in close contact with the rock. And I think that it would be well to find out by experiment whether the addition of lime, which might be obtained by burning the rock which crops out in every field, at very little cost, would not tend to its amelioration.[1]

Other varieties of surface clay.

The other rocks of which these hills are composed also weather into clays of various colours and composition, protected from erosion in a similar way to such an extent, that it is often difficult to find a single outcrop of solid rock for miles together. The colours and consistency of these clays often give a useful, though rough, guide to the nature of the rock beneath, and I append a list of them:—

Formation.	Colour of surface clay.
Gneiss and mica schists . .	Bright red, often micaceous and sandy. (These are the red clays mentioned by Dr. Noetling in his account of the tourmaline mines of Möng Lông referred to above).
Chaung-Magyi Series . . .	Variegated, of light colours. White, buff, yellow, or pink.

[1] In the year 1907 I submitted a note to the Government of Burma, suggesting that experiments should be undertaken by the Agricultural Department of the Province, with the view of discovering whether the addition of lime to the clays of the Shan Plateau would not increase their fertility. If the productive capacity of the soil could be enhanced, to even a small extent, it would open to permanent settlement many thousands of acres of land now practically barren, in a country possessed of a salubrious climate and an abundant rainfall. But, so far as I am aware, no steps have yet been taken to give effect to this suggestion.

Naungkangyi beds . . .	Variegated. Mainly yellow, sometimes orange red, reddish brown, or lilac.
Hwe Mawng beds . . .	Lavender or lilac when dry becoming purple when moist.
Námhsim (lower)	Brown and generally sandy.
Námhsim (upper)	White or buff.
Plateau Limestone . . .	Bright red. On the Permo-Carboniferous rocks blue-grey, or yellow.
Námyau beds	Violet red, or dark purple.

(b) *Calcareous Tufa.*

Calcareous dams.

The enormous extent to which the limestone of the plateau is being removed in solution by percolating waters has already been alluded to, and it is not surprising to find that, when the water comes again to the surface in springs and rivers, and is either evaporated or loses the carbonic acid which keeps the carbonate of lime in solution, the deposits thrown down should reach correspondingly huge dimensions. Indeed I doubt whether any other limestone tract can show deposits of this kind of such magnitude, at least in the open air. In the ordinary 'Karst' region the evaporation usually takes place as the water trickles into the caverns and hollows worn out of the rock, with the formation of stalactites and stalagmite; but in the Shan States there are no open caverns in the great bulk of the limestone, owing to its universally shattered condition, which causes the mass to settle down as underground solution proceeds; though in the super-jacent, more compact, Permo-Carboniferous limestones caverns are common enough. Thus the carbonate of lime which would ordinarily be deposited on the walls of caverns and fissures is in this region brought to the surface and thrown down in the open. The brecciated structure of the rock also allows water to percolate freely through the mass in all directions, and this no doubt adds to the rapidity with which it is dissolved.

Mode of occurrence.

The mode of deposition of the carbonate of lime as travertine in the beds of the rivers is of some interest, and presents some problems not altogether easy to solve. So far as the smaller watercourses are concerned there is no difficulty, because these are either entirely dried up

or reduced to a mere trickle of water in the dry season, and in the natural course of events the carbonate is thrown down as a precipitate as the water evaporates; but the case of the larger perennial rivers is different. In these the deposits take the form of dams or natural weirs, from a few inches to six feet or more in height, extending across the river from bank to bank, and as level along the crest as if they had been built by human hands. A remarkably fine example is seen in the foreground of the view of the Mánsang falls (Frontispiece). They are especially numerous in the Nammá and Námyau, above their conflux with the Nám-Tu; in the upper part of the Nám-Tu itself; and in most of the tributaries of these rivers (Plates 17, 18, and 19); but there are none in the Nám-panhsé above the Gokteik gorge or in the Námhsim; because these rivers flow through non-calcareous rocks.

Causes of growth.

The dams are to be found at those points where, in an ordinary river, we would expect to find rapids separating one reach from another; and it is this peculiarity in their position that constitutes the chief difficulty in accounting for their formation. The first explanation that occurred to me was that in such places the water is thrown into violent agitation, thus affording a ready means of escape for the carbonic acid holding the carbonate of lime in solution, and that the latter was thrown down on the spot. But it is evident that most of the carbonic acid must escape very soon after the water reaches the open air, and that the first rapid encountered should insure its dissipation. That this is actually the case is shown by the colour of the water seen when at rest in the deep pools; for it has a milky, greenish-blue tinge, exactly like that of a reservoir which has been treated with quick-lime in order to soften the water, caused by the minute particles held in suspension. Moreover, the water of these rivers has been found by analysis to contain no more than the usual proportion of solid matter in solut n. A sample

Solid matter in solution.

from the Námyau at Se-In, (**G** 2) collected near the end of March, when he river was almost at its lowest point, gave only 22·3 parts of solid matter per 100,000; while that of the Nám-Tu at Hsipaw, where there are no calcareous deposits, showed even a higher proportion, 29 parts per 100,000, at the same season. Both of these ratios are near the average amounts contained in the waters of ordinary rivers, less indeed than in the Thames, the

water of which contains about 33 parts per 100,000;[1] all of which indicates that the proportion of carbonic acid dissolved in the water is no more than the normal.

Again, if the carbonate of lime were thrown down at these places, it is evident that the rush of water would sweep the particles into the still reaches, where we would expect to find them settling down and forming beds of calcareous mud, but it is not in the pools that the growth of the travertine takes place. Some other explanation therefore must be found to account for the phenomenon.

Action of mosses.

The dams have all the appearance of being in a state of active growth, after the manner of a coral reef, and the resemblance is the more striking because the growth is most rapid along the lip of the fall, where the water is most agitated, so that the edge frequently overhangs the pool below (Plate 19), just as the growth of a coral reef proceeds most rapidly where the waves beat upon it. Yet there is no indication in the substance of the travertine of any organic structure, though leaves, twigs, shells, and the remains of insects add materially to its bulk. In one or two instances I have found small portions of it built up of the tubes of some calcareous-secreting larva, but very little is formed in this way. I noticed, however, that wherever the surface of the deposit is in what may be called an active state of growth, it is clothed with the fibres of a minute, bright green moss; and although this does not appear to have the power of secreting carbonate of lime, since the fibres, so far as I can ascertain, do not contain this substance, yet it may afford an explanation of the growth of the tufa. The *modus operandi* I conceive to be as follows:—In the first place, probably when the river is low, the sand and pebbles on its bed become coated with a film of carbonate of lime, filtering out the particles from the water as it flows over them. And here human agency may in some cases, though not in all, come into play; for the Shans are in the habit of placing fishing weirs on the rapids, built of stakes driven into the bed of the river, and bound together with wattles, leaving an opening at which the fish collect for their passage up stream, and over which the fisherman sits on a small bamboo stage or "machan," waiting his opportunity to scoop them out with

[1] A. Geikie, Text Book of Geology, 4th Edn., Vol. I., p 488.

a net (Plate 20); and I have observed that the leaves and twigs which are caught by the obstruction are often bound together into a solid mass by the tufa deposited upon them, even when the weir has been built but a short time. In most cases, however, I am convinced that the whole of the structure is of natural growth, for they are found in places where no fishing weirs could be built.

Nature of growth.

As soon as a film of tufa has been formed, the moss finds in it a favourable soil, and proceeds to cover it with a network of fibres. These filter out the particles of carbonate of lime from the flowing water, and the growth of the dam begins. The growing surface, so to speak, is of a spongy texture, and has a mammillated appearance caused by aggregations of minute granules of carbonate of lime mingled with vegetable fibres. No doubt the decomposition of the latter, as they become buried in the growing tufa, assists by the formation of carbonic acid to bind the mass together. The more rapid growth along the lip of the fall may perhaps be brought about because it is here that the mosses are most exposed to the light which is favourable to their growth. Thus, although the accumulation of the travertine is mainly due to purely mechanical causes, it depends to some extent on the growth of a living organism, and it is this factor that gives to these dams their outward resemblance to coral reefs.

Occurrence in Nám-Tu.

I have already mentioned that, as regards the Nám-Tu, the calcareous dams are only to be found in the upper part of the river, before it enters the deep gorge above Ta-pangtawng. The reason seems to be that, as it passes through this gorge, it receives so great an influx of pure water from the sandy and argillaceous hills on its right bank that the particles suspended in it become too greatly diffused to enable the deposition of a film of tufa to take place. There is a very fine series of dams at the point where the Nammá joins the Nám-Tu, at the railway bridge above Hsipaw (Plate 17), but they end abruptly at the conflux, and below this none are to be seen, at least so far as I have been able to follow the river, that is to say, down to the ferry at Tong-ang. In the rivers that flow to the Salween from the Loi Ling area and Loi Twang they seem to be rare, at any rate within the part of the country now described, but there are some good examples in the Nám-hen near Kehsi-Mansam, and they are almost certainly to be met with wherever

the rivers flow for any distance through the limestone.

Deposits from springs.

In addition to the calcareous dams in the rivers, masses of travertine are deposited by every spring and in the bed of every stream, often reaching very large dimensions. The scarped cliffs along fault lines and the precipitous sides of the gorges are generally festooned with huge masses depending like curtains from their crests; and where the conditions are favourable these masses may extend completely across the gorge and form a 'Natural Bridge.' Of such a nature is the famous 'Natural Bridge' in the Gokteik gorge, which was for ages used by the Chinese and Shans as a means of crossing this deep canyon with their trains of pack bullocks and mules, and now carries the supports of the great railway viaduct. I have already given an account of this bridge in our *Records*,[1] and it will be sufficient to say that it appears to have been formed by an accumulation of tufa, deposited mainly by springs on the southern side, which has gradually filled the narrow space between the vertical walls of the cleft. Further to the east again, on the descent to the crossing over the Námhsim, before reaching Bawgyô, the railway passes through a cutting several hundred yards long and a hundred feet or more in depth, entirely excavated in travertine deposited by springs issuing from the hill side above the line (Plate 21).

'Natural Bridges.'

Clays, etc., impregnated with calcareous matter.

Where the travertine is deposited by feeble springs issuing from fissures beneath the red clay, the latter is converted into a very hard, cellular, argillaceous limestone, generally of a pink colour, and often containing large numbers of recent land shells and leaves. Sometimes also, where the carbonate-laden water of a stream from the limestone area flows through a ravine in the older, non-calcareous rocks, the tufa will bind together fragments of the latter into a limestone breccia, which may form a very hard, superficial layer several inches thick on the surface of the older rock, and may easily be mistaken for the outcrop of an interstratified band. A freshly broken surface will, however, always show either a minutely porous or a banded fibrous structure of the matrix, which at once indicates its recent origin.

[1] The Natural Bridge in the Gokteik Gorge; *Records, Geol. Surv. Ind.*, Vol. XXXIII, Pt. 1, p. 49.

(c) *River Alluvium.*

River alluvium.

The broad straths along the river and stream courses, which constitute the only permanently cultivated ground in the States, are generally composed of clays, more or less sandy according to the nature of the rock drained, of grey or yellow colours contrasting strongly with the red clay of the surrounding hill slopes. They contain a considerable proportion of calcareous matter, deposited from solution, and are extremely fertile when irrigated, as is almost invariably the case; the ground being artificially terraced up to the highest point at which water from the hills can be led on to the fields, often through well engineered channels of considerable length. The principal crop grown on these irrigated fields, known as 'Na' cultivation, is paddy or rice, but a certain proportion of leguminous crops is also produced. Tobacco is mainly grown along the banks of the rivers, on the beds of rich silt left when the floods have subsided; and among the Eastern Ranges, oranges are largely grown along the smaller streams, on the narrow triangular area of rich alluvial soil which is found where the ravines open out into the main valley.

(d) *Peaty Deposits.*

Peaty deposits.

In certain localities, usually on the gentle slopes surmounting the crest of a scarp, the water issuing from springs, instead of depositing its burden of calcareous matter at once, sweeps away the covering of red clay, or perhaps prevents its formation. In such places a rank growth of aquatic plants and grasses springs up, and in time gives rise to the accumulation of a black soil resembling peat, among which outcrops of the solid rock may generally be found. These peaty areas are often of considerable dimensions, and may be easily recognised by the short green grass which covers them and by the absence of trees. They are common about Nawnghkio, the station on the southern side of the Gokteik gorge, and they seem to be almost confined to such positions as this, that is to say, where the plateau is gently undulating and there is no very high ground in the neighbourhood, so that the water of the springs has no very long course underground, and is consequently not saturated with carbonate of lime.

CHAPTER XV.

MANDALAY-LASHIO RAILWAY TRAVERSE.

In order to present a concise review of the stratigraphical features of the Shan plateau described at length in the foregoing pages, it may be interesting and useful to give here an account of the geology that may be observed along the line of railway connecting Mandalay with Lashio; for, with a few exceptions, all the formations mentioned are to be met with on the line itself; while those that are not actually seen in the cuttings may be visited conveniently from one or other of the numerous railway stations. Many years will probably elapse before communications are so improved that visitors will be able to travel to localities far removed from the railway without having to make arrangements for a regular camping outfit.

Irrawaddy plain.

On leaving Myohaung, the junction with the main line near Mandalay, the railway traverses the alluvium of the Irrawaddy valley in a south-easterly direction for about 12 miles. To the north Mandalay Hill is seen rising above the city, composed, as well as other isolated hills surrounded by the level alluvium, of crystalline limestone and gneiss traversed by granite veins, belonging to the gneissic series of Mogôk. These rocks also form the long range of hills closing the view to the west, on the opposite bank of the Irrawaddy, and along their base may be seen deeply indented terraces of yellow sand-rock, which have yielded a rich harvest of late Tertiary mammalian remains.

Tonbô.

The level ground continues to the first station, Tonbô, immediately to the north of which the limestone rocks of the Shan plateau emerge from beneath the alluvium, forming a series of ridges gradually increasing in height until the main ascent is reached at Sedaw. The beds at Tonbô, which are quarried for lime-burning and road-metal, dip steeply towards the plain, and the same dip, more or less accentuated, is seen in all the ridges. At the point of the ridge nearest to the station (Loc. 27, **B** 5) the rock contains a fair number of fossils (of which *Fusulina elongata* Shum. is the only species determined), most of them corals converted into white calcite, and easily distinguishable on the surface of the dark-blue limestone in which they are imbedded. A band of shelly limestone, filled with fragments of brachiopod shells, occurs at the southern end of the second ridge near Kyuwun, but no fossils worth collecting were obtained here.

Tonbê to Sedaw.

From Tonbô to Sedaw the line rises very gradually over a low fan, formed of gravel and boulders washed out from the Sedaw gorge. To the south the lofty mountain known as the Myaleit-daung, on the opposite bank of the Myitngé (Nám-Tu), attracts the eye by reason of its bold craggy pinnacles. This hill also is composed of the Plateau Limestone, dipping steeply towards the plains.

Ascent from Sedaw.

At Sedaw we begin the ascent to the plateau by a series of zig-zags terraced out of the hill side, which is a dip-slope of almost bare limestone steeply inclined to the west. Sections of gastropods and bivalves may be seen here and there on the weathered surface of the rock, but are all converted into calcite and useless to the collector. On turning the shoulder of the hill and passing through a very short tunnel the beds bend over and dip towards the north-east, continuing so for a few hundred yards to a narrow saddle, immediately below the third Reversing station, at the head of a deep ravine running down to the Sedaw river. Here a sudden change takes place in the character of the rocks. The saddle and the ridge beyond is composed of red shaly limestones, which by their intensely crushed appearance and slickensided surfaces suggest the proximity of a fault. They belong in fact, to the Naungkangyi series, probably to the upper part of it or Nyaungbaw stage, and are brought against the grey limestones by a great fault, which can be traced for many miles to the north and south. Here they contain no fossils, except a very occasional fragment of a crinoid stem or *Orthoceras*, converted into calcite; but the rich collection of cystidean remains described by Dr. Bather in Mr. Cowper Reed's Memoir was made in the ravine mentioned above. This locality (Loc. 88, **B** 5), however, is almost inaccessible from this point, but it may be reached conveniently by a path leading from Sedaw station along the bank of the river and passing round the northern end of the hill of the zig-zags.

Fault.

Fossils.

Line below Zebingyi.

Leaving the fourth and uppermost Reversing station, the line passes through a deep cutting and two 'cut and cover' tunnels, excavated in greatly crushed shaly limestones with a high easterly dip, probably belonging to the Nyaungbaw stage, but without recognisable fossils. Neither the lower brachiopod-bearing Naungkangyi beds nor upper variegated shales with trilobites, etc., are seen here, being

presumably overlapped along the line of the fault. On emerging from the cutting the line crosses a narrow neck formed of the same beds, and a glimpse may be obtained to the south of a vertical scarp of the Plateau Limestone, the edge of a small outlying plateau in which these limestones rest almost horizontally upon the upturned edges of the rocks we have been passing through, the Námhsim beds being absent. The limestone is reached a little further on, and at its base is a small exposure of black, carbonaceous, shaly limestones containing *Tentaculites elegans* Barr. These are the Zebingyi beds, but they are very poorly developed here. In a disused quarry close by some grey flaggy limestones may be seen, which belong to the same formation, and contain *Orthoceras*, either weathered out on the surface or seen in section; but when I last saw it this quarry was overgrown with jungle and hardly recognisable.

Tentaculites beds.

Winding along the edge of a scarp overlooking the Sedaw gorge the line gradually mounts, through a series of cuttings in the limestone, in some of which

First plateau.

From a sketch by the author.

Fig. 10. Contortion in Plateau Limestone, near Zebingyi.

sudden contortions of the strata may be observed (Fig. 10), until it reaches the top of this little plateau and runs for a few hundred yards on the level. It then crosses a narrow ravine which marks the line of a fault, bringing up the red Nyaungbaw beds again, with irregular easterly dips; and these are followed immediately by the Zebingyi beds, the series of strata being repeated. A fine section of these beds is seen as the line climbs the Zebingyi scarp (Loc. 38, **B** 5). For the first half of the ascent flaggy grey limestones, similar to those exposed in the quarry mentioned above, with *Orthoceras* and an occasional shaly band containing *Tentaculites elegans*, are passed through. Near the top of these flaggy beds the fine specimen of *Phacops* (*Dalmanites*) *Swinhoei*, described and figured by Mr. Cowper Reed on page 140 of his Memoir on the lower Palæozoic fossils of the N. Shan States, was found, immediately below a deep cutting through the black graptolite beds. The graptolites here are rather difficult to detect, and are not well preserved, but swarms of *Tentaculites* may be seen on the bedding planes of the rock. The black limestone is succeeded by flaggy grey limestones without fossils, forming the base of the Plateau Limestone, and these are soon followed by the more massive and intensely crushed dolomitic variety, which constitutes the small plateau on which Zebingyi is situated. The dip of the whole series is to the east-north-east or north-east at low angles, but is somewhat irregular. The only organisms found in the limestone near the station are a few crinoid stems or ill preserved corals, visible on the weathered surface.[1]

Fault.

Zebingyi scarp.

Fossils.

Leaving the station the line ascends a gentle dip-slope, the limestones being bent up and dipping to the north-west, forming a shallow syncline with Zebingyi in the centre. At the head of the incline an insignificant cutting is passed through (Loc. 39, **B** 5), in which, and in the trenches beside the line, the Zebingyi beds appear again, and though much attenuated in thickness, contain graptolites in a much better state of preser-

Zebingyi plateau.

Fossils.

[1] When I passed through Zebingyi for the last time, in 1907, a quarry had been opened in the red Nyaungbaw limestone at Yemeyé, about three miles to the south, and the stone was being brought down to the station for despatch to Rangoon, to be used in the building of a new Government hospital there. This rock contains large numbers of the peculiar fossil *Camarocrinus asiaticus* Reed, and excellent specimens were to be obtained from the heaps lying in the station yard.

vation than at the lower locality. They rest upon a bed of hard limestone weathering into a sandy marl, in which the pygidia of *Phacops shanensis* Reed and casts of *Orthoceras* are common, but the latter are reduced to dust and are not worth collecting.

Pyintha flexure.

A blank space of two or three hundred yards follows, succeeded by a steep rise to the plateau on which Thondaung stands. The line works along the northern end of this rise, overlooking the Sedaw gorge, through a series of cuttings in more or less flaggy limestones belonging to the Nyaungbaw stage. Fossils are not common, but an occasional crinoid stem or *Orthoceras* may be found. *Camarocrinus asiaticus* should occur here, but it has not been found in the railway cuttings, though it may be obtained in large numbers on the strike of these beds above Yemeyé (Loc. 71, **B** 5), a few miles to the south, where the cart road ascends this rise on the way to Pyinthá. The rocks form a dip-slope facing west, but at the northern end they bend over into the Sedaw gorge, and the railway runs along the crest of an anticlinal fold.

Section at Thondaung (Fig. 5, p. 169).

An interesting section is exposed immediately beyond Thondaung (Waboyé) station (Loc. 42, **B** 5). On the station platform shaly limestones belonging to the Nyaungbaw stage are seen, dipping east at about 20 degrees. These are followed, just outside the station yard, by the Zebingyi Tentaculites beds, succeeded in turn by a poor exposure of the Plateau Limestone. Then there is a blank of about 50 yards, beyond which the flaggy Nyaungbaw limestones appear again in a short deep cutting, brought up by a fault and dipping eastwards at about 50 degrees. At the northern end of the cutting the topmost bands of these limestones are seen to be much eroded, and reddish shales with *Tentaculites elegans* rest directly upon them (Plate 9), dipping in the same direction, followed, after an interval of some two or three hundred yards, in which the dip becomes much lower, by Plateau Limestone. Thus the section between the station and the cutting is repeated. When the railway was under construction fine specimens of graptolites,

Fossils.

Tentaculites elegans, and *Modiolopsis shanensis* were to be obtained in the 'borrow pits' beside the line, but they have now become silted up, and it is not easy to obtain fragments of the rock. A conical hill of limestone overlooking these pits is noteworthy as the site of

an iron mine, from which the place, Thondaung, takes its name. The mine, which does not seem to have been much more than a prospecting adit, is now filled in, but the ore may have occurred as the infilling of fissures in the limestone.

Main plateau.

The lowest beds of the Plateau Limestone are well exposed in the cuttings further on, and are more flaggy and sandy than usual, but they soon give place to the crystalline dolomite, which continues the whole way to Maymyo, with the exception of a small cutting passed through a little to the west of Letkaung, at the foot of the final ascent (Loc. 26, **B** 4). Here there occurs one of the few bands of shale that are interstratified with the limestone, but the only fossil found in it is a small *Lingula*. The Zebingyi beds are not seen again on the railway, but they run parallel to it on the north, along the crest of the precipices that flank the Sedaw gorge, and approach the line closely at Myenigôn (Loc. 40, **B** 5), near Ani-sakán station.

Naungkangyi beds.

At Letkaung, mentioned above, the Naungkangyi variegated shales approach to within a short distance of the line, but are not cut through by it. In fact, from Thondaung to Hsipaw, a distance of 104 miles, measured along the railway, it passes almost without exception over the Plateau Limestone. The Naungkangyi beds may, however, be conveniently visited from Maymyo, as they form the whole of the hills lying within two miles to the north of the town. The fossil localities of Palin, Ledet, Lebyaungbyán, and Makyinú (Locs. 81-84, **B** 4), are all within a day's ride, and along every path, wherever the rock is exposed, the remains of Cystideans and other fossils may be collected.

Wetwin.

Beyond Maymyo the line runs across the limestone plateau to Wetwin, where it descends a precipitous scarp facing the valley of the Ke-laung stream, from the crest of which a fine view of the plateau may be obtained closed on the east by an even-topped scarp following the line of the great Kyaukkyan fault. At our feet the village of Wetwin is seen, nestling in a shady grove of jack-fruit trees (*Artocarpus integrifolia*), and built upon the only exposure known of the Wetwin shales (Loc. 29, **C** 4). Outcrops of these beds may be found in the watercourses and in the banks of the lanes surrounding the village, but are apt to be much concealed by vegetation. The middle Devonian locality of Padaukpin may also

be conveniently visited from this station, as it lies only a mile away to the east (Loc. 30, C 4). The outcrop of the fossiliferous band lies just outside the western gate of the village, and the fossils may be picked out in large numbers from the surface clay. Some good examples of calcareous dams may also be seen in the bed of the picturesque Ke-laung stream close by (Plate 19).

Wetwin to Kyaukkyan.

Proceeding onwards from Wetwin the line runs for a considerable distance over an almost level expanse of the Plateau Limestone, surrounding the town of Hsum Hsai (Thonzé). The chief point of interest in this stage of the journey is the extraordinary number of streams that are crossed, all flowing from the hilly ground to the north, and gradually bunching together until they join the Hpawng-Aw, running along the foot of the Kyaukkyan scarp, causing the map of this tract to look like that of a delta reversed (Fig. 11 on next page). Two explanations of this multiplicity of streams have suggested themselves to me. Either the valley was covered, at no distant period, with a layer of the Napeng shales, which has now been entirely removed by denudation, but at so recent a date that the streams, issuing from numerous springs in the hills to the north, have not yet had time to excavate deep channels in the hard limestone floor. Or, and this seems the more probable explanation, the streams are so choked with travertine that they are unable to deepen their channels; on the contrary their beds are so quickly filled up with this deposit that they are constantly changing their courses, giving rise to the anastomosing network of channels which we see. There is, it must be said, no evidence that the Napeng shales once extended over the whole of this area, though there are two small mounds, composed of yellow shales, on the railway between Hsum Hsai and the Kyaukkyan scarp, which may belong to this period: but they contain no recognisable fossils.

Kyaukkyan.

We now come to the Kyaukkyan scarp, which has been growing more and more well defined since we left Wetwin. To the south a long line of precipitous cliffs of limestone curtained with thick deposits of travertine marks the crest, but at the gap where the railway and cart-road cross it these are not conspicuous. At this point the rise takes the form of a uniclinal flexure in the limestone rather than a fault scarp, and the ascent from the valley we have left is only about 400 feet, but

Flexure.

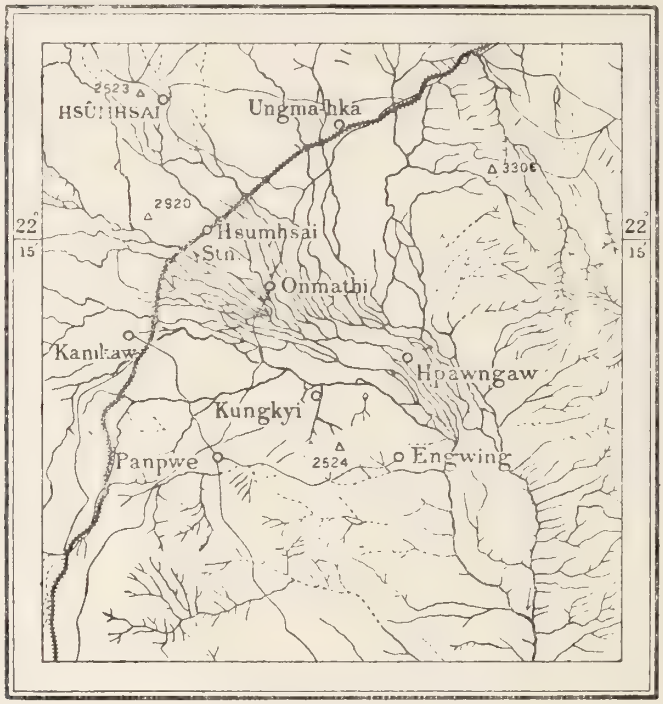


FIG. 11. Branches of the Hpawng-aw R. on the Plateau of Hsum Hsai.
Scale 1" = 4 miles.

Fault.

there is a distinct fault along the crest, with a down throw to the west. Further to the south, however, the throw increases until the relative difference in level becomes about 3,000 feet, and the rocks underlying the limestone, the Námhsim and Naungkangyi beds, are brought up to the surface. At the pass the fault has preserved a patch of the Napeng shales, and of the hard blue limestones beneath them, the latter being exposed in the 'borrow pits' on the ascent and the shales near the crest, just before the line enters a deep cutting through the limestone (Loc. 11, **D** 3). The shales dip towards the fault and are full of fossils, which may be collected either at the side of the line or on the cart-road above. The limestone in the cutting is intensely crushed, and traversed by beautifully polished 'slickenside' planes, evidently due to the proximity of the fault.

Gokteik gorge.

From this point the line runs to Nawnghkiô, where the descent to the Gokteik gorge begins, over an almost level plateau, with a fine view, across the valley to the north, of the rugged hilly country beyond the Nam-panhsé, composed of the Chaung-Magyi slates and quartzites. The richly fossiliferous locality of Chaungzôn (Loc. 96, **D** 3), where the brachiopod-bearing lower Naungkangyi beds are exposed, may be visited from here. It lies on the cart-road, which descends the scarp to the north of the village by a series of zig-zags, at the point where the river at the bottom of the gorge first comes into view. The variegated upper Naungkangyi shales are also exposed between this point and the Chaungzôn bridge, but not very clearly. The railway descends the scarp further to the south-east, to the 'Natural Bridge' and viaduct, where the officials have provided a comfortable bungalow for the convenience of tourists, many of whom visit the place during the cold weather to view the wonders of the gorge. On the descent numerous cuttings are passed through, for a considerable distance in Plateau Limestone dipping towards the gorge, and near the viaduct in travertine deposits which thickly clothe the slopes above the deep cleft through which the river flows. The opposite side of the gorge is a vertical wall of massive limestone, thickly festooned with travertine, which the railway climbs diagonally through a series of tunnels and loops to a plateau on the same level as Nawnghkiô.

Sink-hole at Nawngping.

Beyond this nothing of interest is seen until Nawngping is reached. Two miles to the north of this station is the curious 'pipe' mentioned on page 287, filled with shaly clays containing crustacean remains, probably of Napeng or Rhætic age, and encrusted with an ancient travertine deposit (Loc. 12, **D** 3). From this point to Pyaunggaung the line runs entirely through the Plateau Limestone.

Sections at Namsaw.

From Pyaunggaung a visit may be made to Námsaw, or as the Shans call it, Mong-tim, a village lying about 5 miles to the north-west, where, within a space of less than two miles square, all the Palæozoic formations mentioned in these pages, with the exception of the lower Naungkangyis, may be seen; but the structure of the ground is so complicated that it is difficult to make out the relations of the formations to each other. Looking westwards, the lofty hills across the Nám-Táng, on the banks of which the village is

built, are composed of the highly inclined Chaung-Magyi rocks. At the base of these there is a fringe of Námhsim sandstones, forming a precipitous scarp overhanging the river; and at the base of these again, just above the river, appears the purple, schistose-looking limestone at the top of the Naungkangyis, followed by the variegated shales of the same formation.

The straths on both sides of the river are on Plateau Limestone, which may be seen cropping out here and there, cut off from the scarp by a fault of considerable throw. To the north of the village the Námhsim sandstones form a densely forest-clad hill, apparently the end of a long dome-shaped east and west fold, probably faulted along its northern limb, which disappears abruptly on the river bank; and behind this the Naungkangyi beds are exposed, at the foot of the zig-zags on the road leading across the hills to Mông Lông, backed by the Chaung-Magyi rocks. The amount of faulting and folding that seems to have taken place in this angle is extraordinary; and the ground is so concealed with rainwash and vegetation, generally at the most critical points, that although I spent several days over it, I was unable to satisfy myself as to the true structure. Specimens of *Pliomera ingsangensis* may be collected in this neighbourhood at Hweyawt (Loc. 95, **D** 3), and at the foot of the main range of hills north of Námsaw (Loc. 94, **D** 2).

Faults.

The main area of the Napeng beds may also be reached conveniently from Pyaunggaung, by a road branching off from the cart-road at Ky-wai-kông, about 5 miles north-east of the station, the whole distance being about 10 miles. Fragments of the shales are first met with on a ridge about half a mile short of the village of Napeng, and are *in situ* in the bed of a small stream just beyond (Loc. 15, **E** 3), and at the village itself. The outcrop in the stream bed is exceedingly rich in fossils, and most of the species peculiar to these beds, including *Pteria (Avicula) contorta* Portl. *Grammatodon Lycettii* Moore, *Gervillia praecursor* Quenst., *Protocardia contusa* Healey, as well as fine specimens of the new genus *Burmesia*, may be obtained.

Napeng beds.

Fossils.

Returning to the railway, from Pyaunggaung eastwards the line passes over Plateau Limestone for several miles, running parallel to the foot of the dome-shaped fold in the Námhsim sandstones

Pyaunggaung to Kyaukme.

mentioned above. Just two miles short of Kyaukmé station it cuts through the very end of this dome, and in a cutting here are exposed the richly fossiliferous marls of Kônghsá (Loc. 55, **E** 2), which have yielded good specimens of *Encrinurus konghsaensis* Reed, *Orthis biforata* Schloth., *Fenestella sp.*, etc. The rock exposed in the cutting is exceedingly friable, and it is by no means easy to preserve the specimens; but it may be harder further in, and it might be worth while to make a deeper excavation at this spot. From Kyaukmé the fossiliferous locality of Manaw (Loc. 52, **E** 2), which lies about 7 miles to the north, at the crest of a scarp of Námhsim sandstone overlooking the Námhsim, may also be visited; but the band in which *Orthis biloba* occurs in such profusion is rather difficult to find, as it is only six inches or so in thickness.

Kyaukme to Námhsim.

Eastwards from Kyaukmé the line runs for several miles over a level plateau. About half-way between the station and Loihkaw some highly contorted carbonaceous shaly beds are exposed in a trench beside the line, in which specimens of a minute *Estheria* and fragments of plants may be obtained (Loc. 31, **E** 2) (Fig. 6, p. 255). Beyond Loihkaw the line begins to descend towards the Námhsim crossing, and on first sighting the river winds round the end of a lofty promontory of limestone covered with a thick deposit of travertine, through which the railway is carried in a deep cutting. The cavernous nature of the deposit is well seen here (Plate 21). At the eastern end of this cutting Napeng beds appear from beneath the travertine, dipping north towards the river, and outcrops are seen at intervals in the trenches beside the line for a distance of about a quarter of a mile.

Fossils.

This is the Hson-oi locality (Loc. 13, **E** 2). The beds are more calcareous than at Napeng, and are highly fossiliferous in places. Specimens of *Burmesia lirata*, *Protocardia contusa*, and the little gastropod *Promathilda exilis*, all described and figured by Miss Healey, are the most common forms. In a deep 'borrow pit' between the railway and the cart-road large masses of the blue limestone at the base of the shales may be seen, with corals, *Lophosmilia præcursor* and *Isastræa confracta*, visible on the weathered surface. Masses of these limestones also occur on the slopes between the line and the river below.

First appearance of Namyan beds.

Immediately beyond this the railway crosses the cart-road, and at the crossing the red Námyau beds appear for the first time, dipping north at about 45 degrees. They are highly weathered and friable in the cuttings along the line between this point and the railway bridge, and contain no fossils. Across the river to the north they are found at the base of a vertical scarp of the Plateau Limestone, which marks the line of a fault running along the north side of the Nám-Tu valley, which we now enter upon. The salt wells of Bawgyô are situated on the fault, at the foot of the scarp about half a mile to the north of the station.

Fault.

Nám-Tu valley.

Beyond the railway bridge the line enters upon a wide alluvial plain, after passing through a cutting in one of the old boulder terraces deposited in recent times by the Námhsim or Nám-Tu, and runs across this plain to Hsipaw. Nothing of special interest is to be seen in the immediate neighbourhood of the town, except the boulder terraces; but at Ta-ti ferry (Loc. 7, **F** 2), 6 miles to the north-east, one of the limestone bands near the base of the Námyau series is to be seen, containing large numbers of *Rhynchonella*. The outcrop is on the left bank of the river, about a mile above the ferry, at the mouth of a picturesque gorge from which the Nám-Tu issues. The conglomerate band at the base of the series is also visible in the banks of the river below the limestone. Another of these bands of limestone may be reached from Hsipaw, by following the river down to Bawgyô, where it crops out on the left bank directly opposite to the village. The rock here yields numbers of *Terebratula* as well as *Rhynchonella*.

Excursion to Panghsa-pye.

From Hsipaw also an excursion may be made to the village of Panghsa-pyé, lying 7 miles to the north-west (about 10 miles by the road), on the way to Nám-Hsan, the capital of the Tawng-peng State. At Panghsa-pyé the Llandovery graptolite band at the top of the Naungkangyi beds, and its relations to the rocks above and below, may be studied. The road runs northwards over the Hsipaw plain for two or three miles, and then passes over an old boulder terrace to Na-kiô, where it enters a valley in the Plateau Limestone. This continues as far as Pangmakláng, where it is succeeded

by the Námhsim sandstone. A little further on, near Námsiô, we come upon the southern end of the great Lilu overthrust, which appears to be cut off by a cross fault running along the valley we have been ascending, and this brings up the Naungkangyi beds, which fill the whole of the valley below Panghsa-pyé. The road follows the upper margin of these beds, and the purple band at the top, crowded with crinoid stems and containing an occasional trilobite, is seen at intervals. Fragments of the white graptolite shales may also be picked up, but their outcrop is above the path, and concealed by rain-wash and jungle. They are *in situ* on the saddle on which Panghsa-pyé is built, at the foot of a sandstone scarp, a quarter of a mile to the south-east of the village (*Loc.* 65, **F** 2). The outcrop is apt to be concealed, but may easily be found by working upwards from that of the purple band, which is well exposed on the narrowest part of the saddle. Fossils are also to be found in the Námhsim sandstones forming the scarp above, and in the lanes of the village itself good collections may be made from lower members of the Naungkangyi group. The plane of the overthrust may be reached by following the path leading westwards along the crest of a narrow ridge for about half a mile, and is recognisable by a sudden change in the character of the rocks, the shales giving place to sandstones, though the dip preserves the same direction, to the south-east. Poorly preserved specimens of *Orthonota* and *Pycnomphalus* (?) may be found in these sandstones, showing that they are of Silurian age, though they dip below the Ordovician shales.

Lilu overtrust.

Continuing the railway journey from Hsipaw eastwards, about four miles above the town the valley of the Nám-Tu closes in, becoming narrow and V-shaped, and from this point onwards the line is carried along the banks of this river or its tributaries, the Nammá and the Námyau, to within a few miles of Lashio. The red sandstones and shales of the Námyau series are well exposed in a series of deep cuttings along the whole of this part of the line, generally showing very high dips, as the railway cuts diagonally across the compressed north east—south-west folds into which the rocks are thrown. Fine examples of ripple marking may be seen on the surface of the layers of sandstone in the deep cuttings near Hsunlông (**F** 2), but as a rule these beds are not interesting. About 12 miles from Hsipaw the Nám-Tu issues from a narrow gorge in these rocks and

Hsipaw to Se-in.

joins the Nammá at right angles, as if the former river were the tributary stream. Immediately above the conflux a fine series of travertine dams in the Nammá is visible from the railway bridge, ending off abruptly at the pool where the rivers unite (Plate 17). Above this point these dams are rarely absent from the views of the river that we obtain as the train proceeds, and add much to the beauty of the scenery. A perfect example spans the river close to the platform at Se-in (Se-Eng) station, and may be inspected while the train halts. Near this station also collections may be made from one of the limestone bands in the Námyau series, outcrops of which will be found on the line about a mile to the west, and again about two miles to the north-east of the station, probably belonging to the same band. The latter outcrop is the more fossiliferous, and good specimens of *Terebratula* and *Rhynchonella*, as well as oysters in profusion, may be collected (Loc. 8, **G** 2).

Se-in to Manhpwi.

About 5 miles above Se-in the line begins to mount the hills on the right bank, at a point where the river makes a right-angled bend and after a short course resumes its former direction. On the ascent, after rounding the lower bend, a magnificent series of falls, extending like a giant salmon-ladder for more than a mile up the river, comes into view, flanked on either side by precipitous slopes of limestone (Frontispiece). The sudden bend in the river marks the line of a cross fault, bringing down the red beds against the Plateau Limestone, and the falls are due to the comparative rapidity with which the softer red sandstones and shales below the scarp have been eroded, while at the same time the river has cut back a narrow gorge through the limestone. The intense crushing that the red beds have been subjected to near the fault is a constant source of anxiety to the railway engineers, for the deep cuttings through these rocks are very unstable after rain, and this has no doubt aided the excavation of the deep bay below the falls. Rounding a sharp curve at the head of a narrow ravine to the west of the falls, the line passes at once on to the Plateau Limestone, which extends from this point to and beyond Mánhpwi station; the boundary with the red beds running parallel and close to the railway, at the base of the hills on the west.

Man-Sang Falls.

Bawdwin mines tramway.

At Mánhpwi the steam tramway from the Bawdwin silver-lead mines joins in. These are situated about 30 miles to the north-west, and the tram line runs for the greater part of the distance,

that is to say, to within 8 miles of the mines, through the red Námyau beds. A bridge then carries the line across the Nám-Tu, and beyond this a descending series of rocks is passed through, including the Plateau Limestone, the Námhsim sandstone, Naungkangyi beds, and the Bawdwin grits and volcanic tuffs.

Mánhpwi to Lashio.

From Mánhpwi the main line continues for about four miles over Plateau Limestone, and then enters the red beds, leaving them again near Inai, and after passing through a narrow limestone ridge, enters the broad valley in which Lashio is situated. This is the present terminus of the railway; but it may be well to complete the account of the traverse by a brief description of the country between Lashio and the Salween.

Lashio to the Salween.

Hot springs.

From Lashio the road descends over a gently sloping, undulating plateau to the Námyau, about 5 miles distant. On the left bank close to the crossing, a large hot spring is situated on a fissure which may be traced running diagonally across the river to the north-east, its course being indicated by the bubbling up of the hot water in the river bed. Just above the crossing the red beds again come in, striking across the valley in the same direction. On the north bank of the river we at once enter upon the late Tertiary silts of the Lashio coal-field, which extend along the road for about 15 miles, resting equally on the Námyau beds and on the Plateau Limestone. They may be recognised by the low, mound-like, grass-covered hills, separated by terraced strips of cultivated ground and sluggish streams, into which they are worn. Beyond the coal-field the road passes for several miles over a hilly tract composed of a broad band of the red Námyau beds, a continuation of the band which is seen on the map running along the northern flanks of the Loi Len range, and which blocks up the valley, the river forcing a passage through it in a deep gorge. We then descend, into another broad valley, in which the large village of Mong-yaw is situated, the floor of which is entirely composed of the Plateau Limestone. An oolitic variety of this rock, which crops out in a group of low hills to the north and west of the village, contains minute Foraminifera, *Endothyra*, *Textularia*, etc., which may be seen in thin sections of the rock under the microscope (Plate 12, figs. 1, 2, and Plate 13, fig. 1).

Lashio coal-field.

Mong-yaw valley.

Foraminiferal limestones.

Loi Len range.

To the south of the valley the ground rises along the northern flanks of the Loi Len range, this slope being composed almost entirely of the Plateau Limestone, which also forms a bold craggy hill, known as Loi Sakh, visible to the south-east. Along the crest of this range the series of lower Palæozoic rocks crops out in a narrow band, resting upon the Chaung-Magyi quartzites and slates which form the whole of the southern slopes. The Naungkangyi beds are also found again on the northern side of the Mong-yaw valley, and are perhaps brought up by a fault, but the geology of that part of the country has not yet been worked out in detail.

Main watershed.

From Mong-yaw to the Salween at Hsopket the road runs entirely over Plateau Limestone, and the only point of interest worth recording is that the main watershed between the drainage of the Irrawaddy and that of the Salween is crossed about five miles to the north-east of the village, within 20 miles of the latter river. The descent to the Salween at this place is gentle, though the river flows in a very narrow valley, so precipitous on either side that the railway engineers have not been able to find a practicable route along it towards the Chinese frontier.

CHAPTER XVI.

HISTORICAL SUMMARY.

Eastern shore of Gondwana land.

The geological history of the Northern Shan States may be said to begin with the Naungkangyi period, when we first meet with definite records of passing events in the shape of fossils, just as the history of a nation, as opposed to tradition, begins with its earliest documents, whether in the shape of coins and writings, or its architecture. At the same time it may be allowable to put forward one or two conjectures regarding the course of events that preceded the opening of the historical period in this region. Whether we accept the correlation of the crystalline limestones and associated gneisses, etc., of the Ruby Mines district with the Dharwar system, or refer them to a still older period, we may suppose that the area occupied by them was continuous, in very early times, with the great Archæan continent which covered so large a portion of the southern hemisphere, commonly known as Gondwana land, and that the separation of the fragment of this continent now remaining visible in Burma took place at a later date. Thus the series of fossiliferous strata now described marks one section of the eastern shore of that continent. We have evidence also that the rocks forming this old land had been actively denuded, and that a great series of elastic rocks had been deposited upon the crystalline floor, before definite indications of the presence of living organisms appeared; but the conditions under which these beds, comprised in the Tawng Peng system, were accumulated, whether marine, lacustrine, or terrestrial, are quite as conjectural as those under which the Vindhyan system of the Indian Peninsula was formed. And lastly, we know that, either towards the end of this period of deposition, or during the interval of upheaval and disturbance that followed it, some exhibition of explosive volcanic energy took place, resulting in the emission of lavas and tuffs of an acid type.

Pre-Ordovician denudation.

Conditions antecedent to deposition of fossiliferous strata.

The nature of the oldest of the fossiliferous rocks that we find deposited upon this ancient sea-floor enable us to form some idea of the conditions that immediately preceded the dawn of the historical period. Wherever they are exposed in contact with the older rocks they contain no coarse material which would suggest the proximity of high land, but consist entirely of fine grained sandy marls and limestones, such as would be accumulated on the sea bottom either at a considerable distance from land, or on a coast separated from the hills by a broad stretch of alluvial plain. The conditions may in fact have been similar to those now obtaining in the country surrounding the Bay of Bengal, where a broad belt of low-lying ground, over which no pebbles or coarse detritus can be found, intervenes between the coast and the hills. Again, the great variation in the thickness of the oldest fossiliferous strata, the lower Naungkangyi beds,—several hundred feet in the western part of the Shan plateau being represented by a band of only a few yards in thickness in the Eastern Ranges,—may be due to the unevenness of the floor of this ancient sea; though it may of course be due to other causes, such as deficiency of sedimentation in the eastern area, or to partial denudation in later times. Taken together these characteristics,—the fineness of the sediments and their variation in thickness,—seem to show that the old land, before being submerged, had been worn down to a peneplain but little raised above the sea level of that time; and that when submergence took place, the sea swept over a very large area, in such a manner that the new coast line was situated at a considerable distance from that portion of the sea-floor on which the fine grained beds that now exist were deposited.

The sequence of events, supposing that the Chaung-Magyi rocks are the remains of ancient deltaic deposits, thrown into folds and denuded before the deposition of the Naungkangyis, might perhaps be compared with what would happen if the Pliocene beds of the Arakan Yoma, which are evidently the deltaic deposits of a great river formerly issuing from the Himalaya to the north, thrown into a series of compressed folds, were planed down to sea level and submerged by the waters of the Bay. Sands and mud would be deposited upon their edges, necessarily fine-grained because the nearest hills, the Assam range and the edge of the Shan plateau, which would form the new coast line, would lie at a

considerable distance, while the thickness of the deposits would correspond to the irregularities of the sea-bottom. And as these Pliocene rocks contain, so far as is known, few organic remains, we should find it difficult to learn, supposing that a fresh upheaval brought the whole series above water, what interval of time had elapsed between the deposition of the highly inclined fluviatile strata below and the marine beds resting upon them.

Comparison with North-East China.

The conditions that prevailed at this time in the Shan States appear to resemble very closely those which are described by Bailey Willis[1] as obtaining in north-eastern China at the beginning of the Sinian period. He thinks that the older rocks, represented by the crystalline Archæans and the Hu-t'o system, the latter of which appears to correspond rather closely with the Chaung-Magyi series, had been reduced by subaerial denudation to a peneplain, and—

"that the lowest strata of the Man-t'o (lower Cambrian) formation were laid down in the shallows, lagoons, and flood-plains of a very low, flat coast, where weak waves, feeble shore currents, and rivers interacted."

Contours of the coast, Yunnan Peninsula.

Regarding the actual contours of the eastern coast of Gondwana land but little can be said at present. We know that the ancient crystalline rocks of the Shan States extend northwards towards the head waters of the Irrawaddy, where they are connected in some way, as yet not fully understood, with those forming the main axis of the Himalaya; and that to the east of them, in Yunnan, a sequence of fossiliferous rocks is found, comparable with that of the Shan States; but unfortunately we know very little of the country between the Irrawaddy and the Brahmaputra. All we do know is that metamorphic rocks extend for a long distance to the north-east of Assam, the Miju Ranges of Dr. Maclaren.[2] And it seems probable that these rocks may have constituted from the earliest ages a prolongation to the north-east of the Gondwana continent, cutting off the basin of the southern 'Tethys,' which washed the northern shores of that continent, from the ancient Chinese ocean, of which the Yunnan and Shan seas formed a part. In this way I would account for the marked discrepancy that exists, until we arrive at the Permo-Carboniferous epoch, between the faunas of the Himalaya and of the Shan States,

[1] Research in China, Vol. II, p. 32.
[2] Geology of Upper Assam; *Records, Geol. Surv. Ind.*, Vol. XXXI, Pt. 2, p. 181.

and the equally well marked affinities of the latter with the faunas of northern Europe. Even in Permo-Carboniferous times it does not appear to be necessary to suppose that this barrier was submerged, as I shall attempt to show later on; and indeed it is possible that, in common with the rocks of the greater part of the Indian Peninsula, this tract has never been submerged beneath the sea, since the pre-Cambrian era. Wedged in between the fields of action of two of the principal lines of thrust, one from the north and the other from the east, it appears to have retained its position during the whole course of geological history. The existence of a permanent land area to the north of Burma would also, I think, account for the peculiar features exhibited by the course of the Salween. For if that river is, as I have suggested, of earlier origin than the Mekhong and the Irrawaddy, as the comparative depth of its valley seems to indicate, it may be comparable in antiquity with the larger rivers of the Indian Peninsula; and if so, continental conditions must have prevailed along its course for an immensely long period of time. The Mekhong, the Irrawaddy with its tributaries, the Myitngé and the Shweli, and the real Brahmaputra, that is to say the portion of it which lies above Sadiya in Assam, are busily engaged in cutting back into the old land, and have deprived the Salween of most of its tributaries. And the reason that it still survives as an independent river is that these more modern rivers have not yet been able to cut down to its level or succeeded in 'beheading' it.

Course of the Salween.

Turning to the south-east and south we are even more ignorant of the trend of the Ordovician coast line, for in that direction, so far as I am aware, no fossiliferous rocks of earlier age than the Plateau Limestone are known to occur, until we reach Australia, which, it is well known, formed a part of the Gondwana continent: but it probably coincided more or less closely with the line of the Malay Peninsula and of the Archipelago.

Southern extension of coast line.

In Ordovician times then we may suppose that the sediments were deposited in a tranquil and rather shallow sea, with an uneven floor, and these conditions seem to have lasted until the Námhsim stage. At this time there may have been an emergence of the coast line to the north, causing an influx of sandy sediment. For these sandstones are confined to the northern portion of our area

Emergence in Silurian times.

and are either much attenuated, or absent, beneath the Plateau Limestone further to the south, wherever the base of the latter is exposed. The occasional presence of boulder conglomerates and coarse grits at the base of this formation also indicates the proximity of a coast; and in one case at least, on the spur above Aunglôk, the boulders have all the appearance of shingle thrown up on a sea beach. Further out to sea deposition seems to have taken place very slowly at this time, and it is possible that some portion of the marls that overlie the Llandovery graptolite band in the Eastern Ranges were contemporaneous with the sandstones of the coast. Towards the close of this stage the sea appears to have advanced northwards again, for thin deposits of marl are found overlying the sandstones, up to the edges of the plateau.

Unconformity between Silurian and Devonian.

The evidence as to whether any considerable disturbance of the strata already deposited took place at the end of the Námhsim stage is somewhat conflicting. It is clear that in some places the Nyaungbaw Limestones had been tilted and eroded before the Zebingyi beds were laid down across their edges, but in other places the sequence appears to be perfectly conformable. This appearance of conformability, however, may be deceptive, for the Námhsim sandstones are exposed almost invariably only along the faces of precipitous scarps, and it is impossible to say whether they had been tilted before the Plateau Limestones were laid down upon them or not. It is pretty certain, however, that the latter were accumulated in a gradually deepening and widening sea, for they overlap everything beneath them; and it seems quite possible that, during the earlier stages of the movements that caused this depression, portions of the older sea-floor were raised above the water level and exposed to denudation. The Zebingyi beds, which are extremely local in development and variable in thickness, may have been deposited in a lagoon or swamp bordering upon one of these raised areas; for they contain a good deal of carbonaceous as well as calcareous matter, and have all the appearance of muds accumulated in shallow basins of no great extent.

Easterly continuation of Indo-Gangetic depression.

The movements that ushered in the deposition of the Plateau Limestone seem to have been of great importance in the history of Gondwanaland, for they may have been the first symptoms, in the Indian region, of that break up of the old continent which was destined to modify so profoundly the distribu.

tion of sea and land in the southern hemisphere in more recent times. If we look at a geological map of India and Burma, we see that the portion of the Shan States that we are now dealing with is in a direct line with the great depression that extends from W.N.W. to E.S.E. across the northern end of the Indian Peninsula, from the Indus, at the point where it breaks through the Salt Range in the Punjab, to the southern flanks of the Assam Range. If we produce this line, which corresponds with the direction of the Himalayan 'foredeep' (*Vor-tiefe*),[1] across the Chin-Lushai Hills and Upper Burma, which are entirely occupied by deposits of Tertiary and Recent age, we find that it meets the western scarp of the Shan plateau at the only point where the Plateau Limestone breaks through the barrier of Archæan rocks, which otherwise extends in an unbroken belt from the head of the Irrawaddy north of Bhamo to the sea at Moulmein. Moreover, the manner in which the Plateau Limestone disappears beneath the alluvium of the Irrawaddy is no less significant. There is no diminution of the thickness of this formation as it approaches the plains, but layer after layer of massive limestone plunges out of sight until we reach the highest beds of the series, with *Fusulina*, at Tonbô. It is evident, therefore, that the full thickness of the formation is present here, and that its actual westerly limit does not mark the original edge of the basin in which it was accumulated.

Archæan rocks in Irrawaddy valley.

Immediately in front of the scarp, however, in the plains intervening between it and the Irrawaddy and on the western bank of that river, we find that the only rocks protruding from the alluvium are portions of the Archæan floor, among which there is no trace of Palæozoic rocks, and this fact seems at first sight a serious obstacle to the supposition that the Carboniferous sea was prolonged westwards.

Origin of western scarps of plateau.

But it is to be observed that these ancient rocks were brought to the surface in upper Tertiary times, since on the western side they are in continuous contact with sandstones of that age. In fact, it is evident that the whole length of the western edge of the Shan plateau is a fault scarp, due to a great fault which, in the portion we are dealing with, is duplicated, one branch following the edge of the alluvium east of the Irrawaddy, while the other

[1] Das Antlitz der Erde, Vol. III, Pt. 2, pp. 335, 581.

crosses the river below Mandalay and divides the range of hills mentioned above from the plains of Sagaing and Shwebo. This range is so narrow, and in common with the isolated knolls rising from the alluvium on the eastern bank has been so deeply eroded in recent times, that it is not surprising that no vestiges of the Palæozoic limestones now remain.

Himalayan 'foredeeps.'

Following the line to the north of west, across the plains of Upper Burma and the Chin-Lushai Hills, and leaving the Assam Range to the right, we meet with no rocks whatever that we know to be of earlier than Tertiary age until we reach the Punjab Salt Range, a distance of over 1,600 miles. This depression is the Himalayan 'foredeep,' already alluded to, now filled with fluviatile deposits. No borings that have yet been made have penetrated to the floor of this depression, and in only three instances can we obtain any knowledge of the strata that may underlie the alluvium and Tertiary deposits. One of these is the Salt Range itself, where a succession of strata extending from the Carboniferous to late Tertiary has been brought up by a fault or series of faults, following the line of the southern scarp, which cannot be of earlier date than the deposition of the upper Siwaliks. Only 40 miles to the south of this fault-scarp, in the Kirana Hills on the Chenab, the ancient rocks of the Indian Peninsula appear, proving that there is no inherent difficulty in supposing that marine strata of the age of those exposed in the Salt Range may not be concealed beneath the Ganges alluvium at equally short distances from its southern edge, further to the east.

The Salt Range.

The Assam Range.

The second instance is that of the Assam Range, along the southern edge of which there also runs a sharp dislocation. Here the oldest fossiliferous beds that are brought to light are of Cretaceous age, but a great thickness of bedded traps, supposed to be the equivalents of the Rajmahal traps south of the Ganges, and of Jurassic age, have also been involved in the upheaval. These are followed by limestones and sandstones of Tertiary age, showing that here also the dislocation took place in late Tertiary or more recent times. There are no Carboniferous or early Mesozoic beds to be seen here, it is true, but the sedimentary strata occupy a narrow strip along the southern slope of the range, and extend to no great distance across the plateau beyond; while the composition of the Cretaceous

beds and the manner of their deposition show that they were laid down on the very edge of the depression,[1] and it does not follow that older marine strata may not exist beneath the alluvium further to the south.

Asakan Yoma.

The third instance of a recent exposure of the old sea-floor is of a somewhat different character, but it lends, I think, some support to my suggestion that the break up of this portion of the Gondwana continent began at about this period, and throws some light on the manner in which the movements originated. It has long been known that rocks of Triassic age exist among the parallel ranges of hills that constitute the Arakan Yoma in Lower Burma, and that they are associated with upper Cretaceous beds (Maestrichtian), with *Cardita Beaumonti*.[2] The Triassic beds contain the well known Himalayan genus *Halobia*, and the species found was identified by Stoliczka as *H. Lommeli*,[3] but is probably distinct. It, is, however, associated with a species of *Avicula* allied to *A.* (?) *Girthiana* Bittner, also a Himalayan type, and thus indicates a somewhat close connection between this area and the southern shore of the 'Tethys' in Triassic times at least. No rocks older than these have been met with among these hills, but there is no reason why Carboniferous or Permian strata should not exist at greater depths below the surface. Here again we have brought to light the floor of a depression that was certainly in existence in Triassic times, but this depression was evidently at right angles to that of the Ganges valley. It is, in fact, the 'foredeep' corresponding to the Burman arc of elevation, just as that of the Ganges valley corresponds to the Tibetan or Himalayan arc. The subsequent history of the depressions has many points in common: both have been filled up, that of the Ganges entirely, and that of Burma partly, by Tertiary and recent deposits; but the advance of the respective earth thrusts has resulted, in the former case in the folding of the Siwaliks

Triassic beds.

Burmese 'foredeeps.'

[1] H. B. Medlicott, Geological Sketch of the Shillong Plateau; *Memoirs, Geol. Surv. Ind.*, Vol. VII, Pt. 3, p. 168: Mr. Medlicott also suggests (Coal in the Garo Hills; *Records, Geol. Surv. Ind.*, Vol. VII, Pt. 2, p. 62) that the Cretaceous coal measures of the Garo Hills were deposited in pre-existing valleys, in which case this side of the depression must have been above water till the end of the Mesozoic epoch.

[2] W. Theobald, Geology of Pegu; *Memoirs, Geol. Surv. Ind.*, Vol. X, Pt. 2, pp. 127-137: G. H. Tipper, Preliminary Note on the Trias of Lower Burma; *Records, Geol. Surv. Ind.*, Vol. XXXIV, Pt. 2, p. 134: Further Note on the Trias of Lower Burma; *Ibid*, Vol, XXXV, Pt. 2, p. 119.

[3] Theobald, *Op. cit.*, p. 135.

along the edge of the hollow, and in the latter case in the folding of strata of similar age along its centre; but I will return to the consideration of this matter later on (p. 357).

Possible sea connection with Salt Range in Permo-Carboniferous period.

If the formation of these depressions was in progress during the Carboniferous period, they would account fo the replacement of the purely European fauna of Padaukpin, and of the stages which preceded it, by the Middle Productus fauna of the Salt Range and Himalaya that we find in the Shan States at the close of that period. But, as soon as these limestones had been deposited, there was either a pause in the submergence or, more probably, the eastern or Burmese thrust predominated for a time over that from the north, and an elevation of the Shan area above the level of the sea took place. This was perhaps merely sufficient to allow the surface of the limestone to be worn into hills and hollows, but it kept the surface above water for a considerable period, through Permian and Triassic times.

Triassic unconformity.

Rhætic submergence.

At the end of this period of emergence the surface of the limestone was again covered by the waters of the sea, and the Rhætic shales and limestones were accumulated on the uneven floor into which it had been worn. This submergence seems to have been quite local, and at the same time the old land surface to the north-east may have been gradually rising, with a consequent advance southwards of the coast line, until the sandy sediment derived from it was swept down and formed the red beds of the Námyau series. Continental conditions had prevailed throughout Central China and Yunnan during Permian and Triassic times, resulting in the accumulation of the red coal-bearing system of Sze-chuan;[1] and these conditions now invaded our area, so that before the close of the Jurassic period, we find a great series of red sandstones and shales, with carbonaceous layers and plant beds, spread over the whole of the eastern border of Gondwana land, from North-eastern China to the Southern Shan States. The connection that I have supposed to exist with the southern 'Tethys' must have been of very short duration, for none of the Jurassic ammonites of the Himalaya has

Advance of Continental conditions.

[1] Bailey Willis, Research in China, Vol. II, Chap. VI.

been found in the limestone bands interbedded with the Námyau sandstones.

Permanent emergence.

The geological history of the Shan States, so far as deposition under marine conditions is concerned, ends with the accumulation of these red beds. In common with the whole of China as yet explored, no rocks of Cretaceous age have been met with,[1] and the subsequent history is one of elevation above the sea level and degradation. The nearest examples of deposition at this period are to be found in the Arakan Yoma and along the southern flanks of the Assam Range, where the work of filling up the Burman and Himalayan 'foredeeps' was actively in progress; and where beds of this age are followed by the Nummulitic limestones and higher Tertiary strata of Assam, the Irrawaddy valley, and the Chin-Lushai ranges. But no trace of any of them has been found to the east of the scrap of the Shan plateau.

Period of emergence.

At what precise period the elevatory forces manifested their greatest degree of activity, that is to say, when the extreme folding and crushing of the rocks took place, is somewhat uncertain. It seems to have been either anterior to that of the Himalaya, or to have proceeded for a time more rapidly, for strata of nummulitic age are known to occur on some of the higher peaks of the latter range,[2] and Suess remarks[3] that the Burmese arc of folding preceded that of the Himalaya. But for the most part these great thrust movements, the one acting from the north and the other from the east, must have proceeded simultaneously, and there is a considerable analogy between the final results attained in each case, though they are of very different orders of magnitude. On the Burmese side we have the Shan plateau corresponding, but at a much lower elevation, with the Tibetan plateau, both of them the elevated floor of an ancient ocean, now undergoing abrasion and reduction to a peneplain. The outer edge of each plateau is bounded by what is virtually a scarp; and though it may seem almost absurd to compare the mighty chains of the Himalaya with the insignificant fringe of Archæan and Palæozoic rocks that borders the Shan

Comparison between Himalayan and Burmese arcs of folding.

[1] Bailey Willis, Research in China, Vol. II, Chap. VI, p. 95.

[2] T. D. La Touche, Re-discovery of Nummulites in Zanskar; *Records, Geol. Surv. Ind.*, Vol. XXI, Pt. 4, p. 160.

[3] Das Antlitz der Erde, Vol. III, Pt. 2, p. 579.

plateau, they certainly seem to bear some likeness to each other from a geological, if not from a physical and spectacular point of view. Both are composed, speaking generally, of rocks older than those of the plateau beyond, and in both cases the main rivers, gathering on the uplands, break across the strike of the rocks through profound gorges. In each case the zone of older rocks is bounded by a great fault, or series of faults, forming the inner edge of the 'foredeep' that separates them from the 'foreland' of the continent beyond. In front of this again we have a zone of Tertiary strata, thrown into folds and greatly dislocated by faults, in the one case occupied by the Tertiary series of the Irrawaddy valley, and in the other by the Siwalik strata of the sub-Himalaya and by the 'Duns,' those wide valleys which separate the sub-Himalaya from the Siwalik ranges. These ranges are represented in the Burmese area by the Arakan Yoma, prolonged to the north into the parallel folds of the Chin-Lushai Hills and the Patkoi range of Assam, and here the order of magnitude is reversed, for in Burma these ranges attain to a far greater altitude than in Northern India. Finally, we have in front of these, on the one hand the broad Indo-Gangetic valley, and on the other the Bay of Bengal and the swamps of Sylhet and Cachar, the former completely, and the latter partially, filled with recent alluvial deposits.

Tertiary diastrophism.

The results of the compressive forces that affected the Shan plateau may be considered under two distinct heads: (i), the production of more or less regular folds, accompanied by overthrust or reversed faults parallel to the strike of the folds, and (ii), vertical faults due to the sagging down of the underlying Archæan floor under the influence of gravity. These latter faults bear no relation to the direction of the strike of the rocks, but follow straight or slightly curved lines for considerable distances and are often at right angles to each other, while they are frequently visible at the surface as long lines of vertical scarp.

The first type of dislocation seems to have preceded the second, for the folds into which the rocks are thrown, especially among the Eastern Ranges, are broken up by faults which cut directly across the undulations of the strata; but it also appears to have persisted to a quite recent period, geologically speaking, though to a very feeble degree in later times, for the silts of the late Tertiary coal-basins are distinctly tilted in places (Plate 16).

(i) Folds and Associated Faults.

Western scarp of plateau.

The folding of the rocks is most conspicuous among the older Palæozoic strata, the massive character of the Plateau Limestone having masked its effects to some extent and compelled this rock to yield by fracture rather than by folding, as I have already pointed out (p. 194). Along the western edge of the plateau, although the Ngwetaung sandstones and the Naungkangyi shales and limestones are thrown, wherever they appear from beneath the Plateau Limestone, into north and south folds, and the latter itself is bent over them, the chief energy of the thrust seems to have been expended in the production of the series of parallel faults to which allusion has already been made (p. 352).

Boundary fault.

The outermost of these is that which bounds the Irrawaddy plain, and has brought up the narrow belt of Archæan rocks along the river opposite Mandalay.

Tonbo fault.

The second, probably a branch of this, cuts off the Plateau Limestone abruptly at the foot of the hills east of Mandalay, and brings it against the Archæan rocks forming the isolated knolls dotted about the alluvial plain.

Sedaw fault.

A third runs due north and south at the back of the hill at Sedaw, and brings the Naungkangyi beds against the Plateau Limestone. This fault has been traced to the north into the valley of the Kyetmaôk, a tributary of the Chaung-Magyi, where it seems to die away, the Plateau Limestone being found on both sides of it, and southwards to the gorge of the Myitngé.

Zebingyi fault.

It is followed by a minor fault to the west of the Zebingyi scarp, which has not been traced northwards beyond the Sedaw gorge, but another fault, rather more to the east, extends from near Kyauktin (**B** 4) down to the Chaung-Magyi at Sagabin, and is probably continued up the valley of that river, bringing the Chaung-Magyi series into contact with the Mogôk gneiss.

Chaung-Magyi fault.

This fault may be connected with the Zebingyi fault, but the intervening ground is so densely covered with vegetation that the connection could not be verified. The Zebingyi fault passes to the south, through Nyaungbaw, where it brings the red Nyaungbaw limestone against the Plateau Limestone, into the gorge of the Myitngé.

Pyintha flexure.

The next dislocation is the folded zone of Nyaungbaw limestones to the east of Zebingyi, which forms the final step up to the main plateau. The rocks on the outer (western) flank of this fold form a steep dip-slope facing west, but further in they become vertical, as may be seen where they have been eroded in the ravines below Thondaung; and there is probably a fault along the crest of the ascent, though the eastern limb of the fold cannot be seen, as it is concealed by the overlap of the Plateau Limestone.

Dinaric type of faults.

This system of faults appears to bear a close resemblance, in its relations to the gulf of Pegu, with which I include the whole of the Irrawaddy valley south of Bhamo, and probably the Bay of Bengal also (for the separation of the latter from the gulf of Pegu by the Arakan Yoma was effected by a very recent upheaval), to the Dinaric system, or fractures of the Karst, bordering the eastern shores of the Adriatic.[1] Prof. Suess indeed himself calls attention[2] to the similarity between the gulf of Pegu and the eastern basin of the Mediterannean bordering the coast of Asia Minor, but the resemblance to the Adriatic seems to me to be still more striking.

Lilu overthrust.

Beyond this rise no evidence of definite lines of folding can be made out,—though the rocks are seldom horizontal,—for the Plateau Limestone conceals everything below it, except at the edges of the plateau, where only a narrow fringe of the older rocks can be seen. It is when we turn the corner of the ancient land area lying to the north, and examine its eastern aspect, that we find further and striking evidence of the magnitude of the thrust, and of the modification of its effects produced by the presence of this unyielding mass of rock, or 'horst.' I have already described in detail the great overthrust fault that runs parallel to the Nám-Tu from Panghsa-pyé to the north (p. 136), and I need only call attention to the fact that this dislocation dies away immediately opposite to the point where the boundary of the Chaung-Magyi series, that is to say the contour of the old land surface, bends suddenly from a general north-south direction to the west.

[1] Das Antlitz der Erde, Vol. I, p. 344.
[2] *Ibid*, p. 771.

Folding of Namyau series.

To the east of the Nám-Tu we have abundant evidence of the effects of this form of dislocation. The red beds of the Jurassic Námyan series are thrown into regular folds striking from N.N.E. to S.S.W., and the Plateau Limestone is also affected in the same way, so that we have a more or less regular series of parallel bands of the two formations, somewhat modified by subsequent faulting. and partly removed by denudation, extending along the valley of the Námyau beyond Lashio.

Structure of Eastern Ranges.

In the Eastern Ranges the dislocations take the form of more or less elongated domes, usually with a core of the more ancient rocks that constituted the floor of the Palæozoic sea. There is a considerable diversity in the direction of their longer axes, and in their shape and size, evidently due to the presence of these old rocks. Thus the Loi-len range, and those to the north of it, beyond the limits of the map, trend east and west, but with a tendency at their western ends to swing round to a south-west direction. The longer axis of the dome-shaped mass of Hwe Mawng and Silurian strata to the east of Loi Ling, on the contrary, runs north and south; and this is also the direction of the ranges east of Möng-Yai, much modified by faulting, and of the folds along the eastern flanks of the Loi Pan—Loi Twang range. The Loi-len range is the only instance in which the Plateau Limestone is now found actually arching over the crown of the dome. In the other cases it has been entirely denuded away, if it ever existed as a continuous sheet, and now occupies only the low ground separating one range from another.

Loi-len range.

The outcrop of the formations concerned thus forms a series of oval bands in plan, broadest in the centre where the maximum elevation has taken place and the old sea floor is brought to the surface, and dying away at either end. In some cases the single intense fold at the centre breaks up into minor undulations towards the ends of the dome. An instance of this structure is exhibited by the eastern end of the Loi-len range. At the western end of this range, below the limestone scarp south of Tileng, the Silurian marls, purple shales, and Naungkangyi beds appear together, forming a compressed band only a few hundred yards in width. Following these eastwards, the Chaung-Magyi rocks appear beneath the Naungkangyis, and quickly widen out, forming

the whole of the southern slopes of the range until, to the south of Loi-len village, they have attained a width in plan of nearly five miles (Section I, Plate 24). They form the northern limb of a great overfold, the axis-plane of which hades southwards, while the southern limb has been let down by a fault of great throw, bringing the Plateau Limestone, and indeed patches of the overlying red Námyau beds against the slaty series. The ribbon of lower Palæozoic rocks mentioned above can be traced continuously along the crest of the range, widening out slightly, but greatly crushed, until at Loi-len the beds are inverted, and dip below the Chaung-Magyis. But further to the east their outcrop increases more rapidly in width, and the single fold opens out and is doubled, the purple beds and Naungkangyis being repeated twice in the cross-section. At the same time the Plateau Limestone mounts up the southern side of the range, and bends over the crest, conforming to the undulations of the beds beneath, and coalesces with the band which covers the northern flanks (Section II, Plate 24).

Loi Pan—Loi Twang range.

The structure of the Loi Pan—Loi Twang range seems to be that of a huge dome faulted in a direction transverse to the longer axis across the centre, so that the southern half of it alone is now visible. The core of Chaung Magyi rocks is very broad at the northern end, but gradually narrows, until to the south of Loi Twang it dies away altogether. The fossiliferous Palæozoic rocks along the eastern flanks form one limb of an immense anticlinal arch, the western limb of which has been faulted down out of sight. To the north, between Möng Lá and Pinghsai (**H** 4), the belt of fossiliferous rocks is very broad, and is partly repeated by a minor fold on the Nám-hen; but to the south of Pinghsai it becomes more narrow and compressed, and near Hwe Mawng there are signs of inversion of the strata. The structure along the eastern side of the ranges east of Möng Yai, in the valley of the Nám Pang, is precisely similar.

(ii) Subsidence Faults.

Origin.

To what cause the vertical faults which have done so much to diversify the scenery of the plateau must be attributed is not quite clear. In their mode of occurrence, especially in the manner in which they are repre-

sented at times by a monoclinal flexure, as in the case of the Kyaukkyan scarp described below, they recall the system of vertical faults on the plateau of Colorado described by Gilbert[1] and Dutton,[2] and they are apparently due to local and deep-seated subsidences of the rocks below the surface.[3] The fact that they follow the maximum degree of tangential folding in point of time seems to me to suggest that the cause of the subsidences may have been an easing off of the compressive forces, when the reaction might have resulted in the production of a certain amount of tensional stress, and consequently a slight opening out, as it were, of the folded strata.

Fault scarps.

The effects of these subsidences are usually manifested at the surface in the form of vertical scarps of limestone, often running in a direct line for several miles across the plateau. The sagging of the strata on one side of the fissure and their stability on the other are well exemplified in the case of the great Kyaukkyan scarp so often referred to in these pages. A short distance to the north of the point where it is crossed by the railway at Kyaukkyan this dislocation is hardly perceptible on the surface, though it probably continues for several miles to the north along the valley of the Nám-panhsé, where the direction of the movement appears to have been in the opposite sense, that is to say, a downthrow on the eastern side of the fault, from what it certainly is to the south. Immediately to the north of Kyaukkyan the dislocation takes the form of a monoclinal roll or flexure in the limestone of the plateau, but a line of actual fracture quickly appears near the crest of the flexure, as may be seen at the point where the railway crosses it. Further to the south the crest remains perfectly level, backed by a plateau rising very gradually towards the edge of the Gokteik gorge, but the flexure increases in importance, while at the same time the fault itself appears as a line of vertical cliffs just below the crest, until the differential movement becomes so great that the older Palæozoic rocks beneath the limestone are exposed along the face of the scarp, which by this time has reached a height, relative to the plateau below, of some 3,000 feet. Along the base the edges

Kyaukkyan scarp.

1 Geology of portions of Nevada, etc.; *U. S. Geol. Surveys W. of 100° Meridian*, Vol. III, pp. 48-57.

2 Geology of the High Plateaus of Utah; *U. S. Geol. Survey*, 1880, pp. 25-54.

3 Das Antlitz der Erde, Vol. I, pp. 164-187.

of the Plateau Limestone are seen inclined at a high angle or even vertical, but the strata are quickly bent into an almost horizontal position, and between the base of the scarp and Wetwin are found everywhere with a moderate inclination towards the east.

Principal fault-scarps.

Several other scarps of this kind are to be met with on the plateau, and are so uniform in character that it will not be necessary to describe them all. At either end they begin with an almost imperceptible roll in the limestone, followed, as the subsidence increases, by a definite break in the surface and a wall of cliffs. In many cases rocks of different formations are thus brought into contact, wherever the throw becomes considerable; as for instance, the Wetwin shales at the base of the scarp north of that village; the red Námyau sandstones at the base of the long line of scarp that bounds the northern side of the valley between Námhsim and Hsipaw; and the same rocks at the base of the scarp that runs from near Onghkôk (**F** 3) on the Nám-Tu below Námhsim to Pongwô (**E** 3) (Plate 10). Of a similar kind is the fault in the valley of the Nám-Tu between Htengnoi and Tong-ang, which has brought down against the Plateau Limestone and preserved a wedge-shaped mass of Napeng beds and the red sandstones overlying them.

Hot springs.

In some cases the line of the fault is marked by a series of hot or tepid springs. Such springs occur on the eastern and southern sides of the block of red beds south of the Nám-Tu at Hsipaw; one near Pengwai and several between Na-kang and Loimawk (**F** 2), while a very important one is to be seen at Nám-ôn (*Shan*, Water-hot) at the point where the continuation of the Loimawk fault would cross the north-south fault running from Hson-oi to Pangsam (**E** 3). The salt spring of Bawgyô, to which reference has already been made (p. 342), is situated on the Námhsim fault, and the salt is probably derived from the red beds which are there brought down against the Plateau Limestone.

Lashio hot springs fault.

There must be many of these faults which do not betray their presence by a visible scarp, either because the rocks on either side have been removed to the same extent by denudation, or because they are not of sufficient throw to bring rocks of different composition into contact with each other. Thus the fissure on which the great hot spring of Lashio is situated does not form a scarp, and would not be recog-

nisable but for the ascent of more than one of these springs along its course. This fault was in existence before the deposition of the Tertiary silts of the Lashio coal-field, for they pass across it without any trace of disturbance on one side or the other. It is for this reason, the identity of the rocks on both sides, that it has not been possible to mark the continuation of some of the faults on the map, though there is little doubt that many of them extend beyond the limits shown.

Faults in Eastern Ranges.

The faults of this character met with among the Eastern Ranges exhibit their presence in a somewhat different way; not by the formation of lines of cliffs, but by the abrupt termination of the fossiliferous bands surrounding the domes. They let down wedge-shaped masses of the overlying rocks among those beneath them, as in the valley of the Nám-Há, where a long triangular strip of the Plateau Limestone, with the Silurian and Ordovician beds below, has been brought into contact with the Chaung-Magyi slates on the eastern side of the valley (Section III, Plate 24). Their direction may cross that of the strike of the rocks at any angle, and they have evidently been formed at a later date than the folds. Here again it is impossible to show the whole length of the faults on the map, for as they die away their throw is not sufficient to bring dissimilar rocks into contact.

Sub-recent geological history.

There remains little to be said regarding the geological history of the Northern Shan States since these events took place. In common with a great part of the continent of Asia, since the period of deposition of the Jurassic sandstones this tract has remained above the level of the sea, and the processes that have modified the surface features are the same that we now see in action, and if long enough continued, will result in the reduction of the whole surface to a peneplain. If we except the folding and faulting described above, only one event took place during this long period of time that is in any way different from those which we now see passing before our eyes; for the deposition of the late Tertiary silts of the Lashio and other coal basins was effected after the present configuration of hill and valley had been established, and differs in no respect from that which is now going on in the lake basins of the Southern Shan States and Yunnan. It belongs, therefore, rather to recent than to geological history.

Volcano of Loi Han Hun.

The event to which I allude is the little outburst of volcanic activity at the time when these silts were being accumulated, already referred to in the account of the Man-sang coal-field (p. 313). It exhibits, it is true, an extremely feeble manifestation of volcanic energy, but it is interesting as the sole evidence of the presence of these forces below the surface that we have met with in our review of the whole sequence of fossiliferous rocks from lower Ordovician to the present time. The situation of this little volcano, at the very base of Loi Ling, the most highly elevated mass of the ancient sea floor on which the fossiliferous series was deposited is, I am inclined to think, significant, as suggesting that if we could probe to a sufficient depth, we would find that the underground reservoirs of molten rock had been brought nearer to the surface at this point than elsewhere; and the particular time at which the outburst occurred also suggests that one or other of the great vertical faults played some part in opening a passage for the emission of the lava.

CHAPTER XVII.

ECONOMIC GEOLOGY.

Early accounts.

As I have already mentioned in the introduction to this Memoir, the earlier notices of the Shan States were confined to vague reports of the abundance of mineral wealth supposed to exist there. More or less precise information was forthcoming with respect to two occurrences only, the Ruby mines of Mogôk and the silver-lead mines of Bawdwin. Of the first of these we have an account by an eye-witness, Père Guiseppe d'Amato, written at some time before the year 1833, in which he gives a description of the methods of working the alluvial deposits in which the gems are found, agreeing in every respect with that given by Mr. Barrington Brown, when he visited the place at least 54 years later. The Bawdwin mines were never visited by a European till the beginning of the present century, some 50 years after they had been abandoned by the Chinese miners, who are said to have worked them for several hundred years. The other minerals which are stated in the older accounts to be extremely prolific in the Lao territory, as the Shan States were then called, are iron, copper, lead, tin, and antimony; but with the exception of lead ore, none of these has been found as yet to be sufficiently abundant to warrant exploitation by modern methods of extraction.

All the more important minerals to be found in the Northern Shan States, and their mode of occurrence, have already been described in papers published at various times in the *Records* of the Geological Survey, and it will therefore be necessary to give only a brief notice of them here.

Antimony.

Nám Hsan.

Some very pure specimens of stibnite were brought to me while I was in the neighbourhood of Nám Hsan (**E** 1), the capital of the Tawng Peng State, said to come from the hills near the town. The prevailing rock in that part of the country is granite, and the specimens had evidently been broken from narrow veins in this rock, but

Mr. Coggin Brown, who made a search for the mineral with the assistance of a native guide, was unable to discover it *in situ.* Specimens of this mineral have also been sent to the Geological Survey laboratory on several occasions by the District officials for report, but in all cases the description of the locality from which they came was too vague to enable it to be traced.

Coal.

Mode of occurrence, and quality.

The so-called coal of the Northern Shan States has already been sufficiently described,[1] and requires only a brief notice here. I have already given an account, in Chap. XIII, of the various basins in which the seams are found. It is a brown lignitic coal containing a high percentage of moisture, as is shown by the analyses given in Table 13, compiled from the various reports, and in its natural state has been found to possess little or no economic value. It is found in the small basins filled with late Tertiary silts occupying the valleys of the streams that rise among the hills surrounding Loi Ling, the loftiest mountain in the States, and sometimes occurs in beds of considerable size, one seam in the Lashio field attaining a thickness of 30 feet. But such a seam as this if followed up would probably be found to thin out rapidly, and none of them appears to be continuous over a wide area. The coaly layers were probably accumulated in swamps similar to those which now surround the lakes that still remain unsilted in the Southern Shan States. For this reason it has not been possible to form any reliable estimate of the quantity of coal available in these basins.

[1] F. Noetling, Coal-Fields in the N. Shan States; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 99: T. D. La Touche and R. R. Simpson, The Lashio Coal-Field, *Ibid*, Vol. XXXIII, Pt. 2, p. 117: R. R. Simpson, The Namma, Man-sang, and Man-se-le Coal-Fields, *Ibid*, p. 125.

TABLE 13.

Analyses of Coal, Northern Shan States.

LASHIO FIELD.

LOCALITY.	SEAM.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.
Hsunkwé, No. 1 outcrop	13 ft.	19·84	35·72	34·84	9·60
	5 ft. 6 in.	18·04	40·16	30·60	11·20
Do. No. 2 outcrop	4 ft.	19·78	32·02	28·64	19·56
Do. Ry. Co.'s No. 3 incline	3 ft. 10 in.	18·94	37·62	29·61	13·83
	4 ft. 5 in.	22·95	35·10	27·62	14·33
	8 ft. 10 in.	19·79	34·79	30·42	1·43
Do. Ry. Co.'s No. 4	6 ft.	19·75	36·06	38·31	7·88
	7 ft.	20·04	36·65	29·72	13·59
Do. Ry. Co.'s No. 10	8 ft.	19·15	23·96	17·13	39·76
Naphá outcrop	4 ft. 6 in.	17·70	35·98	29·72	16·60
Naleng outcrop	11 ft.	17·76	35·64	37·40	9·20
Mong-pá pit	5 ft. 8 in.	21·86	34·00	32·11	12·03

TABLE 13—*contd.*

Analyses of Coal, Northern Shan States.

Locality.	Seam.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.
NAMMÁ FIELD.					
Nammá No. 1 pit	1 ft. 4 in.	15·57	26·55	25·97	31·91
	1 ft. 10 in.	6·04	37·99	20·06	35·91
Do. No. 8 pit	3 ft.	11·84	42·16	39·05	6·95
Do. No. 9 pit	5 ft. 9 in.	17·81	36·09	38·29	7·81
	5 ft. 10 in.	16·37	34·99	38·53	10·11
Do. No. 12 pit	11 ft. 10 in.	18·16	34·96	38·39	7·66
Do. No. 13 pit	7 ft.	17·83	37·38	39·96	4·83
	6 ft.	12·73	40·25	38·87	8·15
Mong Ting, No. 5 pit	3 ft.	13·70	39·56	33·44	13·30
Do. No. 1 pit	3 ft. 5 in.	16·32	37·40	33·25	13·03
Do. No. 2 pit	5 ft. 8 in.	18·16	38·87	31·18	11·79

TABLE 13—*concld.*

Analyses of Coal, Northern Shan States.

LOCALITY.	SEAM.	Moisture.	Volatile matter.	Fixed Carbon.	Ash.
MÁN-SANG FIELD.					
No. 1 pit	3 ft. 2 in. . .	16·09	34·11	33·14	9·76
No. 4 pit	2 ft. 9 in. . .	14·79	34·71	33·17	7·33
No. 8 pit	4 ft. 8 in. . .	13·31	36·78	34·95	14·96
No. 15 pit	1 ft. 9 in. . .	14·66	34·26	39·63	11·45
No. 18 pit	3 ft. 5 in. . .	13·04	33·35	34·58	19·03
MAN-SE-LÉ FIELD.					
No. 2 pit	3 ft. 2 in. . .	14·73	38·83	34·22	12·22

Copper.

Bawdwin.

A few small heaps of copper slag were seen lying on the hills near the Kachin village of Loi Mi, about three miles to the west of the Bawdwin silver mines, and at the head of the valley in which the mines are situated. The ore was probably extracted by the Chinese miners of Bawdwin, but the lode was apparently of no great size or richness; otherwise the relics of their operations would be more extensive. No traces of the ore *in situ* could be found. At Bawdwin itself the face of the cliffs is covered in places with films of the brilliant blue and green carbonates of copper, azurite and malachite, which are also found impregnating the country rock, but although it makes a considerable show, the mineral occurs in exceedingly small quantity. It is no doubt to the colours of these carbonates that the place owes its Shan name, Nam-pang-yun, signifying 'stream of the peacock camp.'

Gem-stones.

Ruby, Sapphire and Spine.

Ruby Mines District.

It is not necessary to give here a full description of the gem-bearing gravels of Mogôk and Kyatpin in the Ruby Mines District, as they have already been described in detail by Mr. Barrington Brown, and the origin of the gems has been discussed by Prof. Judd in a joint paper contributed to the Philosophical Transactions (*see ante*, p. 34 *seq.*). The rubies are derived from the crystalline limestone interbedded with the Mogôk gneiss; but attempts to extract them from the rock *in situ* have proved unsuccessful, and they are obtained from the debris resulting from the weathering of the limestone and associated rocks, either by following up fissures in the former (known as '*loodwin*' mining); by driving cuttings into the rainwash on the hill sides (*Hmyaudwin*); or sinking pits (*Twinlone*) in the alluvial gravels covering the floor of the valley until the gem-bearing layer (*Byon*) is reached. The native methods of working are still to be seen in operation in the valley of Kyatpin (**B 1**), 11 miles to the west of Mogôk; but the principal deposit in the Mogôk valley is being worked by the Ruby Mines Co., who have held a virtual monopoly of the industry since the year 1889, when they were granted the right to mine for rubies and levy

royalties from persons working by native methods. Since the year 1898, when the first dividend of 5 per cent. was paid, the enterprise has been on a sound footing, and in some years dividends of over 17 per cent. have been paid. The proprietors are now engaged in working systematically through the whole of the alluvial deposit, and have installed machinery of the latest design, driven by electric power derived from the falls of the Mogôk river at its exit from the valley. In addition to rubies, a considerable output of sapphires, spinels of various colours, apatites, and tourmaniles is obtained, but the last-named are of the black variety, schorl, and are of no value.

Value of output.

During the period 1898 to 1903, the average annual value of the gems obtained was £89,345, but during the next quinquennial period, 1904-1908, the average value of the output fell off, owing mainly to the general depression of trade in 1907 and 1908, to £83,505, and no dividend was paid for the year ending 28th February 1909.[1] In this year the production was 205,384 carats of rubies, 13,457 carats of sapphires, and 39,463 carats of spinel, with a total value of £58,649.

Námhsu-hká.

The small ruby tract of Námhsu-hká (Namseka) (**C 1**), at the junction of the Mogôk river with the Nám-Pai in Möng Lông State, reported on by Dr. Noetling in 1891,[2] has since been entirely worked out by the Ruby Mines Co., but I can find no record of the value of the gems obtained.

Tourmaline, Möng Lông.

The remains of extensive excavations in search of red tourmaline (rubellite) are to be seen in the valley of the Nám-Pai near the town of Möng Lông (Maing-lôn) (**C 1**), and the mines are still worked spasmodically, with very variable results. The locality was visited in 1887 by Mr. Barrington Brown[3] and was afterwards described by Dr. Noetling.[4] The tourmalines are obtained by washing the gravel of old terraces on the banks of the river, and have evidently been derived from the broad dykes of granite which break through the gneiss of the hills to the north. Within the last ten years the highest output was obtained

Value of output.

[1] T. H. Holland, Review of the Mineral Production of India, 1898-1903; *Records, Geol. Surv. Ind.*, Vol. XXXII, Pt. 1, p. 77: T. H. Holland and L. L. Fermor, *Ibid*, Vol. XXXIX, p. 186.
[2] *Ibid*, Vol. XXIV, Pt. 2, p. 119.
[3] *Op. cit.*, p. 166.
[4] *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 125.

in 1905, when 161 lbs. of rubellite, valued at £1,501, were obtained. In 1907, however, the output fell to 20 lbs., valued at £293, and in 1909 only seven stones are reported to have been found, worth £26. The gems are sold to the Chinese, by whom they are in great demand.

Maingnin.

The tourmaline mines of Maingnin, described by Mr. E. C. S. George in the *Records* in 1907,[1] are situated in the State of Mongmit (Momeit), to the north of the Ruby Mines District. The gems are said to be obtained from a decomposed granite. The mines appear to be worked in a desultory manner, and the output is small, only 5 lbs., valued at £36, having been obtained in 1908, the last year for which returns have been received.

Gold.

Mode of occurrence.

The streams that drain the areas occupied by the slates and quartzites, with their associated quartz veins, of the Chaung-Magyi series, usually carry a certain amount of gold in fine particles, and I have seldom tested one of them without finding at least a 'colour.' Gold washing is practised by the natives in a desultory fashion in many places, when they are not employed in tilling their fields, and the frequency with which gold occurs is denoted by the prevalence of its Shan appellation 'hkam' in their place-names (Loi-hkam, 'gold-mountain,' Nám-hkam, 'golden stream,' etc.). In the year 1906 an attempt was made to exploit one of these alluvial deposits in the Nammá (not the stream from which the coal-field derives its name, but a tributary of the Salween flowing by Mán Námluk (J 1), due east of Lashio), by means of a steam dredger, brought to the spot and put together at the cost of great labour and expense. Previous prospecting operations had shown that an average return of 15 grains of gold to the cubic yard might be looked for, but it was found that the gravel, having been consolidated in places by the infiltration of calcareous tufa was not amenable to the method employed, and after a short trial the enterprise proved abortive.[2]

Namma dredging venture.

[1] *Ibid*, Vol. XXXVI, Pt. 3, p. 233.
[2] General Report; *Ibid*, Vol. XXXVII, Pt. 1, p. 31.

Loi Twang.

An account of some prospecting trials carried out by myself in the streams draining the Loi Twang range has been published in the *Records* of the Geological Survey.[1] The gold occurs in the form of small flat spangles with irregular outlines and a pitted surface, and has evidently not travelled far, but none was found *in situ.* The quantity was disappointing, for except in one case, when a small nugget was found weighing 4·86 grains, it did not amount to as much as 2 grains per cubic yard.

Möng Lông.

Quite recently a more promising occurrence has been brought to light by the Sawbwa (Chief) of Hsipaw, in the sub-State of Möng Lông. This State lies to the north of the plateau and is entirely covered by rocks belonging to the Chaung-Magyi series and by the mica schists. In this case the gold is in larger spangles and some of the specimens consist of quartz grains studded with flakes of gold, suggesting that the metal is derived from the quartz veins which traverse these formations in all directions. The exact locality of this discovery has not yet been made known, but it is hoped that an opportunity will soon occur of examining the deposits.[2]

Iron-ore.

Loi Twang.

In some parts of the Shan States indications are met with, in the shape of heaps of ferruginous slag, that in former times a considerable amount of iron ore was smelted, but in only one instance did I find any manufacture of iron actually going on, and that was on a very small scale. At the southern end of Loi Twang I came upon a party of Tarengs engaged in making 'dha' blades, the large knife which the hill-man has always ready to his hand, which he uses impartially for cutting down trees or an enemy, for splitting bamboos when engaged in house-building, or for slicing his tobacco. The ore is obtained in large masses along the outcrop of the Naungkangyi shales on the eastern side of the range, but the absence of good transverse sections made it impossible to see whether it was a mere surface impregnation of the beds, of the nature

Mode of occurrence.

[1] Vol. XXXV, Pt. 2, p. 102.

[2] Since the above was written, the deposit has been examined and reported on, see *Records, Geol. Surv. Ind.*, Vol. XLII, pp. 37-51. "Report on certain gold-bearing deposits of Möng Lông, Hsipaw State," by J. Coggin Brown.

of laterite, or an interstratified layer. If the former supposition is correct the quantity available cannot be large, certainly not sufficient to keep a modern blast-furnace supplied.

Wetwin.

The ore associated with the Wetwin shales, and that found along the cart-road between Zegôn (Singaung) (**B** 5) and Maymyo, mentioned by Mr. Datta in the General Report of the Geological Survey for 1899-1900 (p. 121), is of the same character. Iron ore is said to have been obtained from a hill close to Thondaung (*Burm*., Iron Hill) railway station, near Zegôn, and I was shown a pit in the side of the hill, which consists of the Plateau Limestone, said to have been an iron mine. No traces of ore could be seen, and the pit was filled with rubbish, but as the top of this hill and of others in the neighbourhood are covered with masses of a rich ore, which may be of lateritic origin, the 'mine' may only mark an attempt of the native prospectors to find out whether the ore penetrates to the interior of the hill or not.

Thondaung.

Limestones and Building Materials.

Variety of composition.

Limestones of very varied composition and quality, ranging from the practically pure calcite of the Permo-Carboniferous formation, through the argillaceous limestones of the Ordovician and Silurian, to the dolomites of the Plateau Limestone, are to be found in the greatest abundance in these hills; but with the exception of a certain quantity of lime, which is burnt at Tonbô and Zebingyi by the most primitive native methods, mainly for local consumption, no use has hitherto been made of them. And yet among limestones of such varied composition it is not unlikely that some might be found suitable for the manufacture of cement, for which there is a very large demand, both in Burma and India. No experiments on an adequate scale, however, have yet been made in order to ascertain whether this is the case or not.

Building stone.

There is very little demand for building stone in the States, though the railway engineers have used both the limestone, and in a few instances, the sandstones of the Námyau series for bridge-building with success; but the Plateau Limestone is usually in too shattered a condition to be of much use in this respect. Some of the harder bands among the

Námhsim sandstones would furnish a durable building-stone, but the outcrops of this rock are too far from the railway to make it worth while to open out quarries, unless a larger demand than now exists were to spring up. The red limestones of the Nyaungbaw group have been quarried at Yemeyé (**B** 5) near Zebingyi, for use as copings and ornamental string courses in the Government hospital lately built in Rangoon, but the rock was selected more on account of its rich chocolate red colour than for its durability, and it is doubtful whether such a stone, traversed as it is by numerous veins of secondary calcite, will withstand the damp climate of Rangoon.

Quarry at Yemeye.

Many of the crystalline limestones of the Ruby Mines District could be used as statuary marble, but this rock occurs in such large quantities in the more accessible Sagyin Hills near Mandalay, and at Kyauksé, on the railway south of that place, that there is never likely to be any demand for the marble of the more remote occurrences, and the only use to which it is put is that of metalling the roads.

Marble.

Clays of sufficiently good quality for brick-making may be found almost everywhere, and are largely used in the construction of pagodas, a pit being opened at each site and the bricks burnt on the spot. The European houses in Maymyo and other towns are usually built of brick, but the natives never employ this material in the construction of their houses, even the 'palaces' of the chiefs, and the monasteries, being built of wood and bamboo. The white kaolin-like clays that occur at one or two localities in the Tertiary coal basins,—at Mán-Sé (**H** 1) in the Nammá coal field, and at Mankün (**I** 2) in the Mán-se-lé field,—might be suitable for making pottery, but hitherto no use has been made of them.

Clays.

Salt.

A considerable quantity of coarse salt is manufactured from the water of a brine well situated at Bawgyo (**F** 2), in the valley of the Nàm-Tu near Hsipaw. The well is sunk on the line of a fault at the base of a limestone scarp, and the salt is no doubt derived from the red Námyau sandstones, which are faulted down against the Plateau Limestone. The produce is exported and sold among the hill

Bawgyo brine well.

tribes living to the east of the Salween, and the revenue is devoted to the upkeep of a large monastery at Bawgyô, where a great Buddhist festival is held yearly. The well was described by Dr. Noetling in 1891,[1] and was again visited by myself in 1905 for the purpose of ascertaining the quantity of sulphate of soda that could be obtained annually, as the water of the well was known to contain a large proportion of this substance, in connection with a proposal to establish the manufacture of wood pulp in Burma. The solid contents of the brine were found to yield about 60 per cent. of sodium chloride and 35 per cent. of the sulphate, and I estimated that, if the crude salt were properly refined, about 70 tons of sulphate could be obtained from this well annually. The present method of refining the product is extremely rough, amounting to no more than stopping the evaporation before it has reached dryness, and throwing away the scale, containing the bulk of the sulphate, which collects on the bottom of the evaporating pans.[2]

Silver-lead Ore.

Bawdin.

A full description of the silver-lead mines of Bawdwin, situated in the northern part of the Tawng Peng State, which have long been famous for their production of silver, has been published in the *Records* of the Geological Survey.[3] The mines had been worked by Chinese, who paid a certain tribute to the King of Burma, from time immemorial, but were abandoned about 60 years ago, probably on account of the unsettled state of the country. The Chinese appear to have made little use of the lead, copper, and zinc contained in the crude ore, but extracted the silver on the spot by cupellation, and threw away the lead slag, great heaps of which, now spread over the sides of the valley in which the mines are situated, testify to the activity of former years. In 1827 Crawfurd[4] estimated the production of silver as worth 960,000 ticals, or £120,000 yearly, of which 4,800 ticals (£600) was paid as tribute to the King of Ava; and so late as 1855 Dr. Oldham was informed[5] that 40 viss (2,276 oz.)

[1] Note on a Salt Spring near Bawgyô; *Records, Geol. Surv. Ind.*, Vol. XXIV, Pt. 2, p. 129.
[2] Note on the Brine-well at Bawgyô; *Ibid*, Vol. XXXV, Pt. 2, p. 97.
[3] T. D. La Touche and J. Coggin Brown, The Silver-lead mines of Bawdwin: *Ibid*, Vol. XXXVII, Pt. 3, p. 235.
[4] Embassy to the Court of Ava, p. 444.
[5] H. Yule, Mission to the Court of Ava in 1855, Appendix A, p. 345.

of silver were produced daily, but that the annual revenue derived by the King of Ava was only 40 ticals (£5). His informant stated that 10,000 Chinese were employed at the mines, a number probably greatly exaggerated.

The extent of the Chinese workings is still perfectly visible, the hill sides being honeycombed with their adits and shafts, of which some 300 have been counted; and the remains of their smelting and cupellation furnaces are still to be seen. So far as can now be ascertained, the ore consisted of lead sulphide, associated with zinc blende, iron pyrites, and chalcopyrite, either disseminated in granules through the country rock or aggregated into large masses. It appears to have been produced by the metasomatic replacement of the constituents of the Bawdwin grits and tuffs by minerals deposited from solutions rising along the plane of the great overthrust fault already described (p. 136). The ore is said to be very rich in silver, picked samples having yielded as much as 87 oz. to the ton of lead.

Lead slags.

The slags rejected by the Chinese miners, amounting it is estimated to over 100,000 tons, are now being removed, by a Company formed for the purpose of exploiting the mines, to Mandalay, where they are smelted. The results of the first year's working were satisfactory, 5,030 tons of lead and 27,500 oz. of silver bullion having been extracted and disposed of in London, the amount realised being £68,100; but owing to very heavy initial expenses, incurred principally in connecting the mines with the Lashio railway by a steam tramway some 40 miles in length, the profits of the enterprise have as yet been small.

Other occurrences.

Silver-lead ore is also found in places among the limestones of the plateau, and one occurrence of this kind, not far from Lashio, is now being worked in order to supply crude ore to be mixed with the refractory slags of Bawdwin for smelting purposes. In 1909, the quantity of ore extracted from this mine was returned as 5,888 tons. There is also a reputed silver mine among the foot-hills near Taunggaung (**B** 4), about 20 miles to the north-east of Mandalay; but the excavation is now almost entirely filled up and overgrown, and no ore is to be seen. The rocks at this locality are limestones belonging to the Naungkangyi series.

Reported discovery of cinnabar.

I have been more than once assured, on what seemed to be good authority, that rich deposits of cinnabar had been discovered in the Shan States, but the material on inspection turned out invariably to be nothing more than red clay. The brilliant red 'Terra Rossa' of the plateau, when washed into a fissure in the limestone, and exposed by denudation in a cliff section, may easily be mistaken for this mineral; but its low specific gravity, as compared with that of cinnabar, at once serves to distinguish it.

LIST OF FOSSIL LOCALITIES.

No.	Locality.	Formation.	Latitude. °	′	″	Longitude. °	′	″	Page.
		TERTIARY.							
1	Hko-hkam .		22	59	30	97	47	45	315.
2	Mán-Sé . .	„	22	47	45	97	55	30	316.
3	Námmá . .	„	22	42		97	51	30	316.
		JURASSIC.							
4	Na-kyeh . .	NAMYAU SERIES .	22	56		97	31		307.
5	Na-hawk .	„	22	51		97	29	15	307.
6	Namhathai .	„	22	47	30	97	27	30	307.
7	Ta-ti . .	„	22	42		97	24		307, 342.
8	Se-in . .	„	22	43	45	97	33	30	306, 307, 344.
9	Tong-ang .	„	22	17		97	23		307.
10	Namhsawm .	„	22	20	15	97	13	45	307.
		RHAETIC.							
11	Kyauk-kyán .	NAPENG BEDS .	22	18		96	46	30	285, 298, 339.
12	Nawngping .	„	22	22	30	96	58		287, 301, 339.
13	Hson-oi . .	„	22	33	30	97	14		285, 298, 342.
14	Nawng-leng .	„	22	30		97	10		290.
15	Napeng . .	„	22	29	15	97	8	30	285, 290, 298, 341.
16	Naunghkam .	„	22	27	30	97	9	30	290.
17	Nawnghkiô .	„	22	26		97	9		290.
18	Námpen . .	„	22	26	45	97	7		290.
19	Hkawkwolam .	„	22	25	30	97	10		290.
20	Na-nim . .	„	22	24		97	8	30	290.
21	Nawngkwang .	„	22	24		97	11	15	290.
22	Námhu-ikkyi .	„	22	23		97	5	30	290.
23	Loi-lam . .	„	22	25		97	6	15	263, 290.

No.	Locality.	Formation.	Latitude.			Longitude.			Page.
			°	′	″	°	′	″	
24	Lukhkai . .	Napeng Beds.	22	55	30	98	13	30	286.
25	Mán-kiô . .	,,	22	56	30	98	16		286.
		PLATEAU LIME-STONE.							
26	Letkaung .	,,	22	1	45	96	28		255, 336.
27	Tonbô . .	,,	21	53		96	15		196, 256, 331.
28	Myainggyi .	,,	21	47	30	96	21		240.
29	Wetwin . .	,,	22	5	45	96	38	30	241, 336.
30	Padaukpin	,,	22	6		96	39	30	196, 336.
31	Loihkaw .	,,	22	33		97	7		255, 341.
32	Námlan . .	,,	22	17		97	21	30	258.
33	Mán-kang .	,,	22	55	30	97	58	30	258.
34	Nám-un . .	,,	22	18		97	41	30	258, 260.
35	Ho-un . .	,,	22	18	30	97	48	0	258.
36	Mán-maw .	,,	22	16	30	97	56	45	261.
37	Kehsi-Mansam	,,	21	55	30	97	52		258.
		SILURIAN.							
38	Zebingyi 1 .	Zebingyi Beds .	21	53	45	96	21		164, 334.
39	Zebingyi 2 .	,,	21	53		96	22	30	141, 167 334.
40	Myenigôn .	,,	21	59		96	27		170, 336.
41	Twinngé . .	,,	21	57	30	96	25		170.
42	Waboyé . .	,,	21	57		96	25	15	168, 335.
43	Kyinganaing .	,,	21	54	45	96	24	30	141, 168.
44	Pyinthá . .	,,	21	51	30	96	24	30	168.
45	Thayetkankyaing	,,	22	6	30	96	32	15	170.
46	Pang-yu . .	,,	22	27		96	39	30	142, 170.
47	Aunglôk . .	Namshim Beds.	22	14	45	96	26		130, 132.

No.	Locality.	Formation.	Latitude.			Longitude.			Page.
			°	′	″	°	′	″	
48	Pomaw . .	Namhshim Beds	22	21	30	96	53		142.
49	Manná . .	„	22	26	45	96	52	30	134, 142.
50	Hkyawngtwang	„	22	38	15	97	4		138.
51	Nammang .	„	22	38	45	97	3		138.
52	Manaw . .	„	22	37		97	4	30	143, 341.
53	Kiohsiô N. .	„	22	37		97	0	30	138.
54	Kiohsiô S. .	„	22	34	45	97	1	30	
55	Kônghsá .	„	22	32	0	97	2	45	142, 341.
56	Um-oi . .	„	22	40	30	97	7	30	
57	Htangsang .	„	22	40	30	97	13	30	138.
58	Longtawktao .	„	22	56		97	20		
59	Lilu 3 . .	„	22	50		97	21	30	138.
60	Hamngai. .	„	21	53		97	42		147.
61	Panghsa-pui .	„	22	59	30	98	13	15	145.
62	Námpung	„	22	20	30	98	24	30	146.
63	Pa-tep . .	„	22	13	15	98	24	15	147.
		LLANDOVERY.							
64	Ngai-tao .	Panghsa-pye Graptolite Band.	22	55	45	97	23	45	128.
65	Panghsa-pyé .	„	22	42	30	97	16	45	126, 138, 343.
66	Pangmé . .	„	22	53	15	97	57	45	128.
67	Pangsam .	„	22	2	30	97	53	30	129.
68	Pinghsai . .	„	21	59	45	97	53	45	129.
69	Kanlün . .	„	22	20	45	98	14		129, 146.
		ORDOVICIAN.							
70	Nyaungbaw .	Nyaungbaw Limestone.	21	50	45	96	20		121.
71	Yemeyé . .	„	21	51	30	96	22	45	119, 121, 335.

No.	Locality.	Formation.	Latitude.			Longitude.			Page.
			°	′	″	°	′	″	
72	Maymyo Reservoir.	Nyaungbaw Limestone.	22	4	15	96	30	45	122.
73	Hwe Mawng .	Hwe Maung Beds.	21	55	45	97	46		85, 96.
74	Nám Há R. .	,,	22	26	30	98	12		95.
75	Hkawnhkôk .	,,	22	21	30	98	11		94.
76	Hwe-hôk .	,,	22	21	30	98	13	45	94.
77	Mong Há. .	,,	22	18	20	98	14	45	94.
78	Nawngyün .	,,	22	20		98	23		95.
79	Hsophi . .	,,	22	12	30	98	23	30	95.
80	Kyaukmô .	Naungkangyi Beds.	22	25		96	25	15	73.
81	Palin . .	,,	22	6	45	96	28		336.
82	Ledet . .	,,	22	3	30	96	27	45	88, 336.
83	Lebyaungbyán.	,,	22	2	15	96	26		77, 336.
84	Makyinu .	,,	22	0	15	96	25	30	77, 336.
85	Sakangyi. .	,,	21	59	30	96	25	15	88.
86	Ngwetaung .	,,	21	58	45	96	20	45	72.
87	Taungkyun .	,,	21	57	30	96	21	30	73.
88	Sedaw . .	,,	21	53	30	96	19		69, 332.
89	Kunlein .	,,	21	52	30	96	26	15	90.
90	Tawmawgôn .	,,	22	32	45	96	33	30	74.
91	Taungmiô .	,,	22	5	15	96	31	15	77.
92	Naungkangyi .	,,	22	4		96	30		78, 89.
93	Ingsang . .	,,	22	35		96	59	45	91.
94	Namsaw . .	,,	22	32	15	96	59	30	91, 340.
95	Hweyawt .	,,	22	29	30	96	58		91, 340.
96	Chaungzôn .	,,	22	21		96	52	15	74, 339.
97	Pangpôk .	,,	22	3	30	96	48	30	90.
98	U-möng . .	,,	22	38	45	97	7	30	76.

No.	Locality.	Formation.	Latitude.			Longitude.			Page.
			°	′	″	°	′	″	
99	Nam-yün .	Naungkangyi Beds.	22	38	45	97	9	45	76.
100	Man-ngai .	,,	22	56	30	97	23	30	92.
101	Ta-pangtawng .	,,	22	56		97	25		92.
102	Lilu 1 . .	,,	22	51	45	97	21	45	85, 92.
103	Lilu 2 . .	,,	22	51		97	21		76.
104	Tileng . .	,,	22	51	0	97	54	30	80.
105	Manshio . .	,,	22	5		97	52		82.
106	Loi kôk . .	,,	21	58	15	97	50	45	83.
107	Hwe-wa . .	,,	21	57	30	97	50		83.
108	Loi Pamông .	,,	21	50	45	97	46	15	83.
109	Loi len . .	,,	22	56		98	2	45	93.
110	Mánkyawng .	,,	22	18	30	98	13	30	81.
111	Poklao . .	,,	22	22		98	23	15	
112	Námtawng .	,,	22	14	30	98	24		82.
113	Mánkawngniu .	,,	22	14	45	98	13	15	82.

GEOGRAPHICAL INDEX.

SUBJECT INDEX.

G

H

M

N

P

Q

R

T. H. D. La Touche. Photo.

LOI-LING (8,771 Ft.) FROM MAN-SANG.

The dome-shaped Tertiary volcano, Loi-Han-Hun, is seen in the middle distance.

T. H. D. La Touche, Photo.

SCENERY OF THE PLATEAU.

View from Man Hka, near Kyaukmé, looking Eastwards. Napeng Hills in the distance.

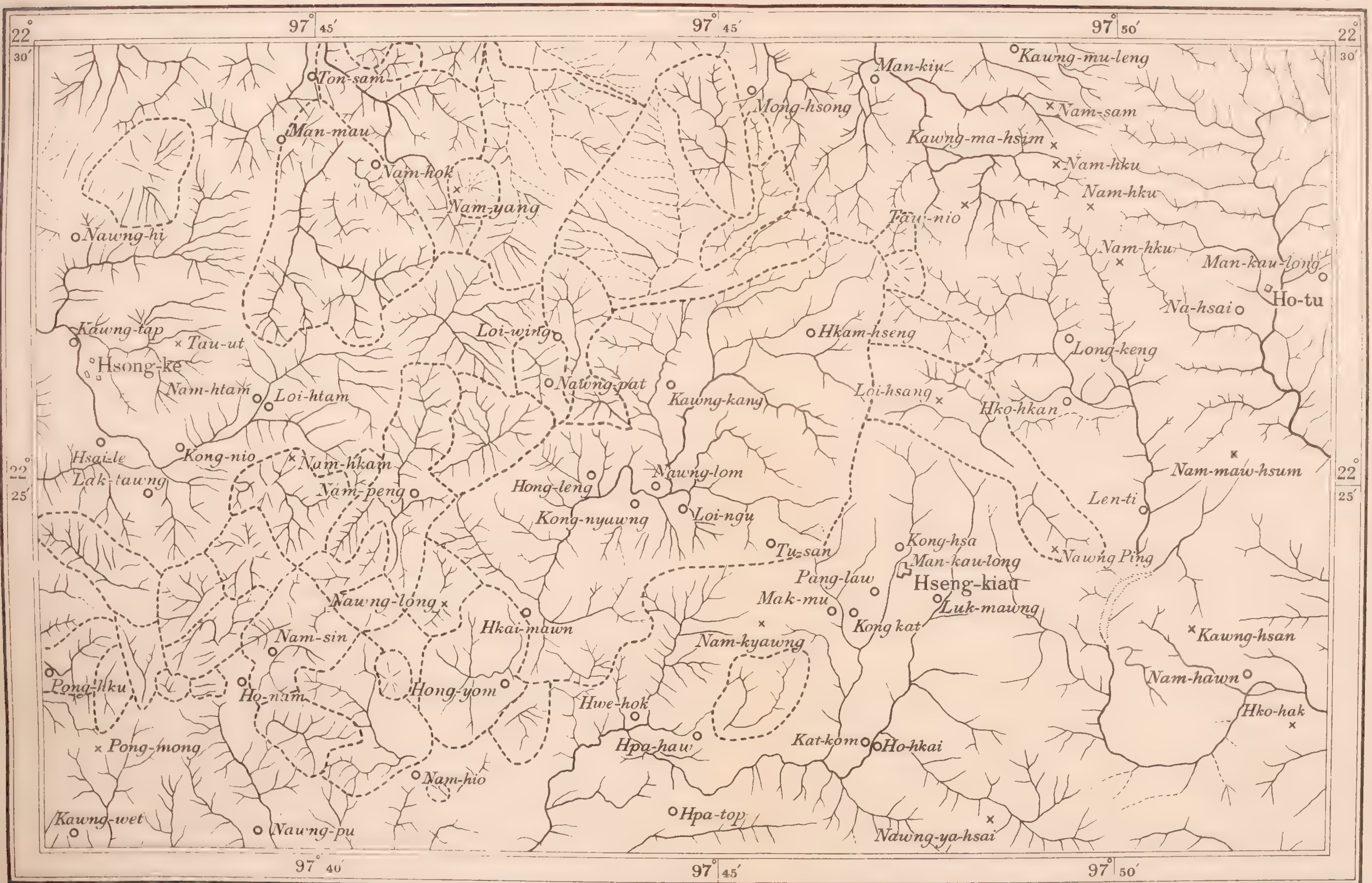
J. H. D. La Touche, Photo.

THE LUKHKAI 'KESSELTAL.'

The drainage of the valley sinks underground in the two hollows surrounded by trees, seen below the village.

T. H. D. La Touche, Photo.

'SWALLOW-HOLE' IN THE LUKHKAI 'KESSELTAL.'



A PORTION OF THE SHAN PLATEAU SHOWING CALDRON VALLEYS. REDUCED FROM SHEET NO. 93 $\frac{F}{11 \& 15}$ BURMA TOPL. SURVEY.

Scale, 1″ = 2 miles.

The boundaries of the Caldron valleys are indicated by dotted lines

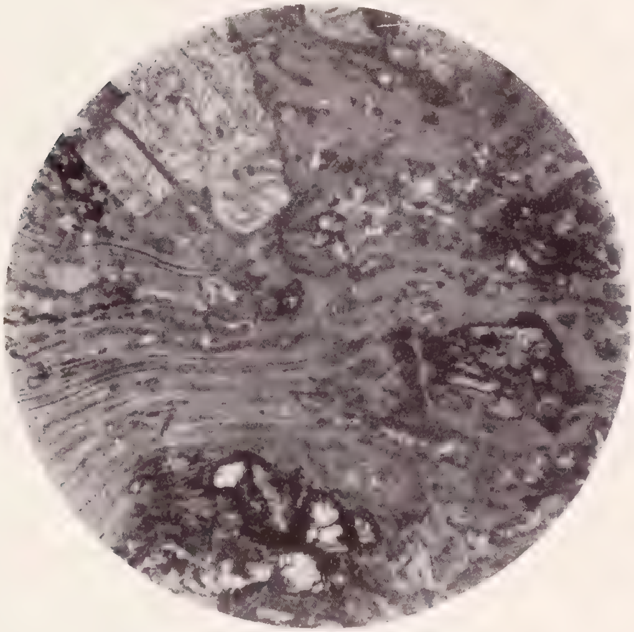
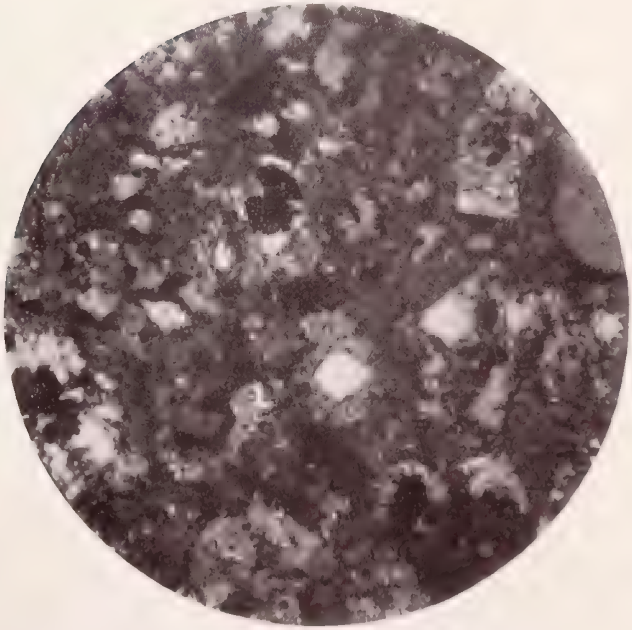


Fig. 1×17. RHYOLITE, BAWDWIN.
Flow-structure.



T. H. D. La Touche, Photomicro.

Fig. 2×17. RHYOLITE, BAWDWIN.
'Quartz mosaic' and secondary growth of quartz phenocrysts.
Nicols Crossed.

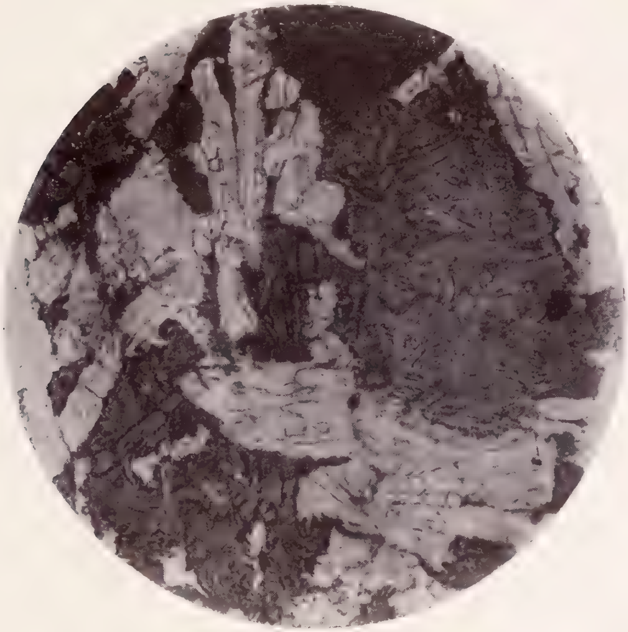
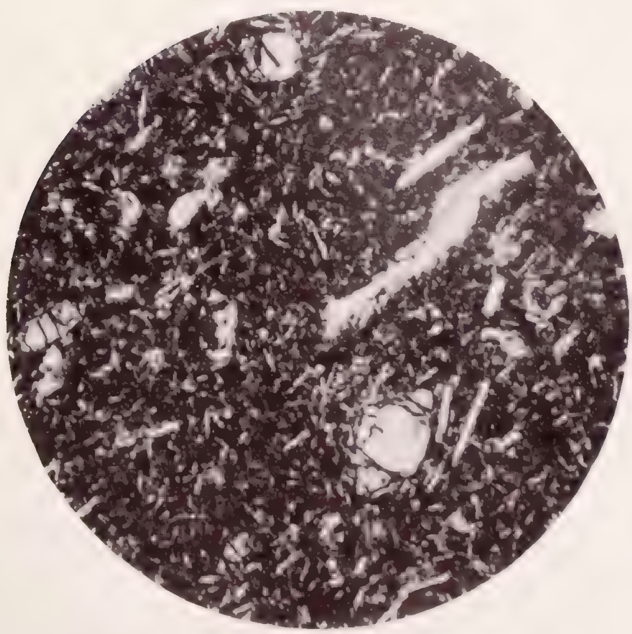


Fig. 1×17. DIORITE DYKE NEAR HPALAM.



F. H. D. La Touche, Photomicro.

Fig. 2×17. OLIVINE BASALT (Tertiary), LOI HAN HUN.

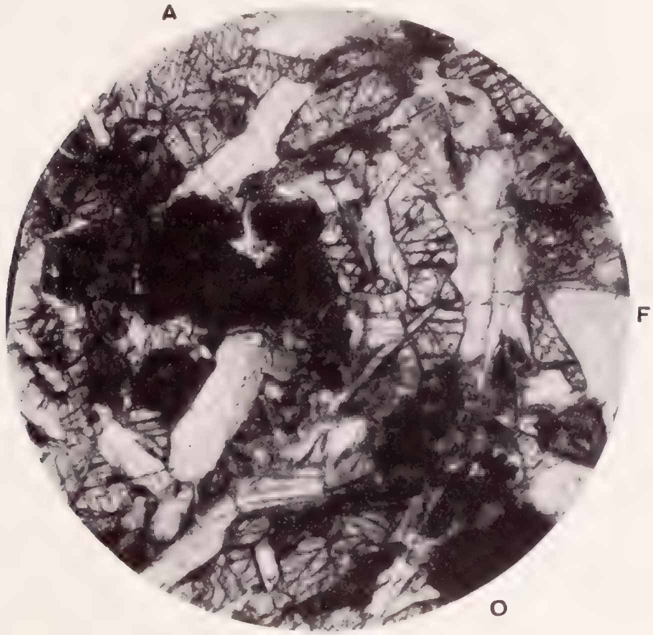
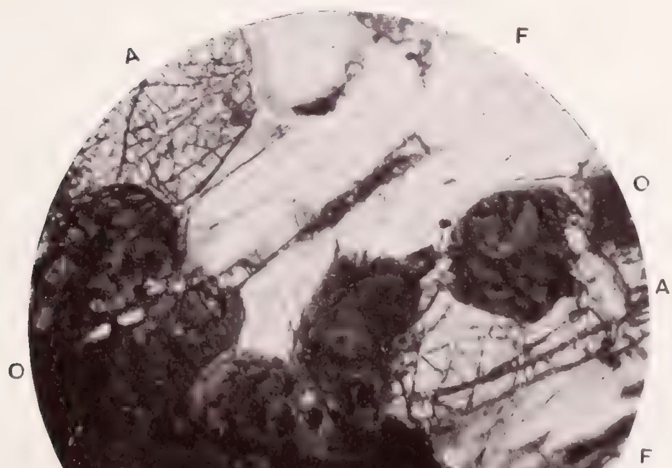


Fig. 1×17. **OLIVINE GABBRO, NAM HSAN.**
A. Augite, F. Felspar, O. Olivine.



T. H. D. La Touche, Photomicro.

Fig. 2×33. **PORTION OF ABOVE ENLARGED TO SHOW 'REACTION RIMS.'**
Surrounding Olivines at contact with felspar

T. H. D. La Touche, Photo.

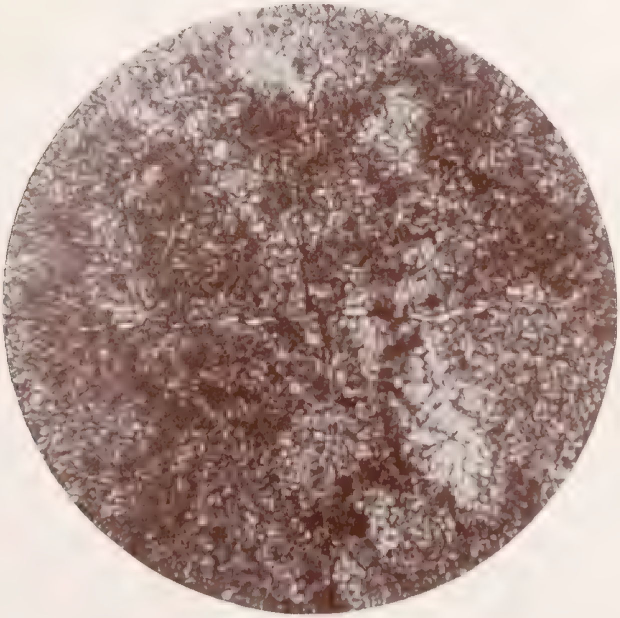
JUNCTION OF ZEBINGYI SHALES (ON LEFT) WITH NYAUNGBAU LIMESTONE.

Near Thondaung Ry. Station.

T. H. D. La Touche, Photo.

FAULT-SCARP AT PONG-WO.

Fig. 1×12. ORDOVICIAN LIMESTONE.



H. D. La Touche, Photomicro.

Fig. 2×17. PLATEAU LIMESTONE.
Ordinary Type.

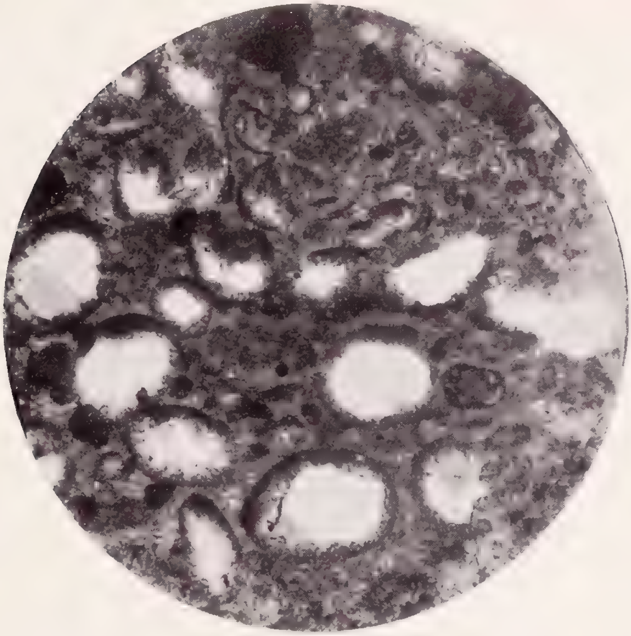


Fig. 1×17. OOLITIC LIMESTONE WITH FORAMINIFERA, MONGYAU.

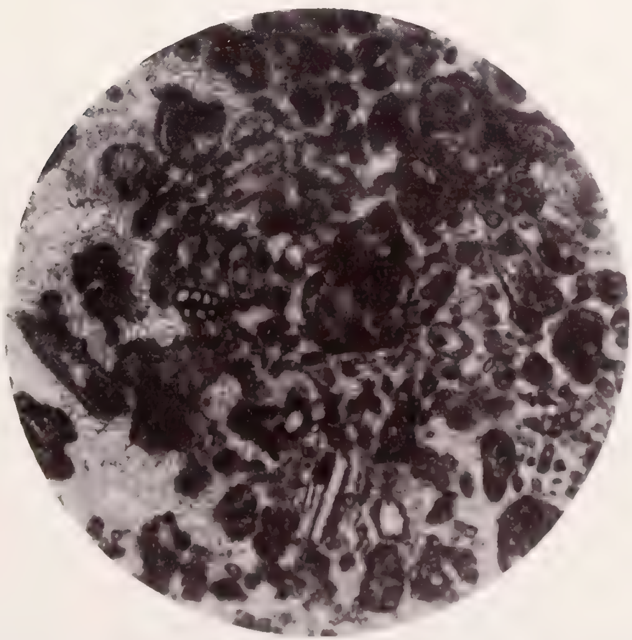


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Fig. 2×17. OOLITIC DOLOMITE WITH FORAMINIFERA, MONGYAU.

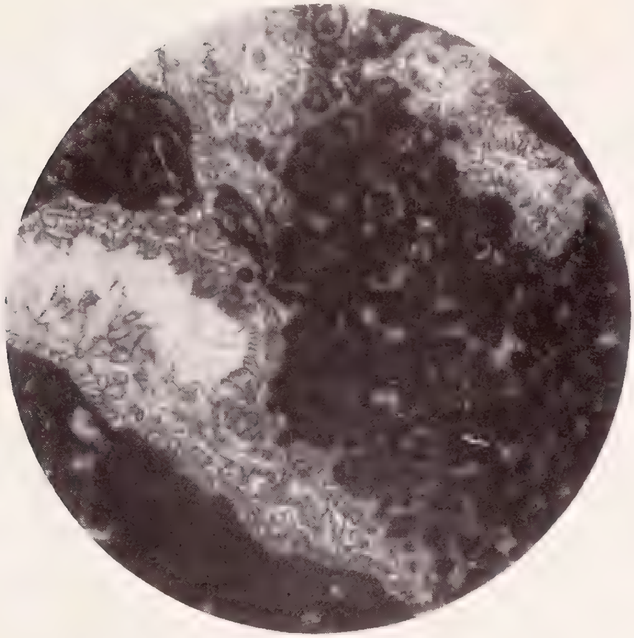
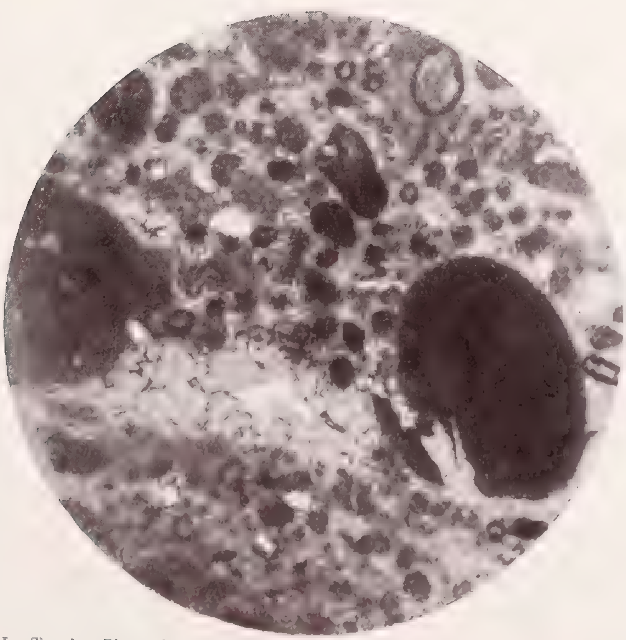


Fig. 1×17. OOLITIC DOLOMITE, MONGYAU.



T. H. D. La Touche, Photomicro

Fig. 2×17. OOLITIC DOLOMITE, GOKTEIK GORGE.

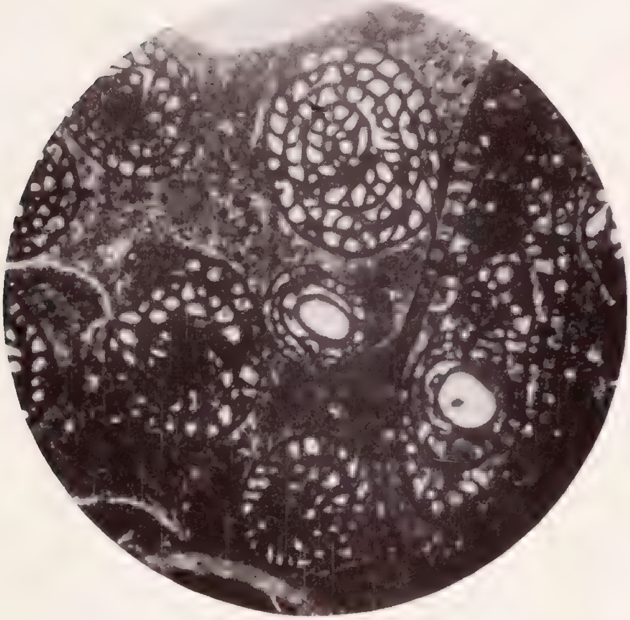
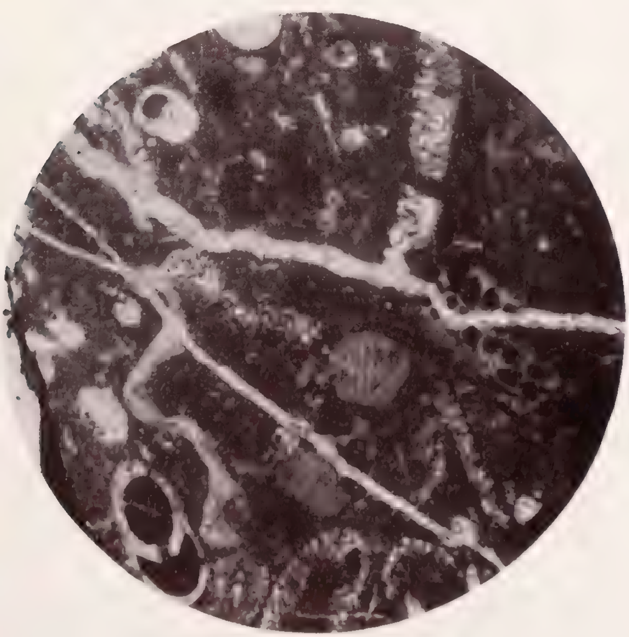


Fig. 1×14. FUSULINA LIMESTONE, KEHSI MANSAM.



F. H. D. La Touche, Photomicro

Fig. 2×14. PERMO-CARBONIFEROUS LIMESTONE, KEHSI MANSAM.

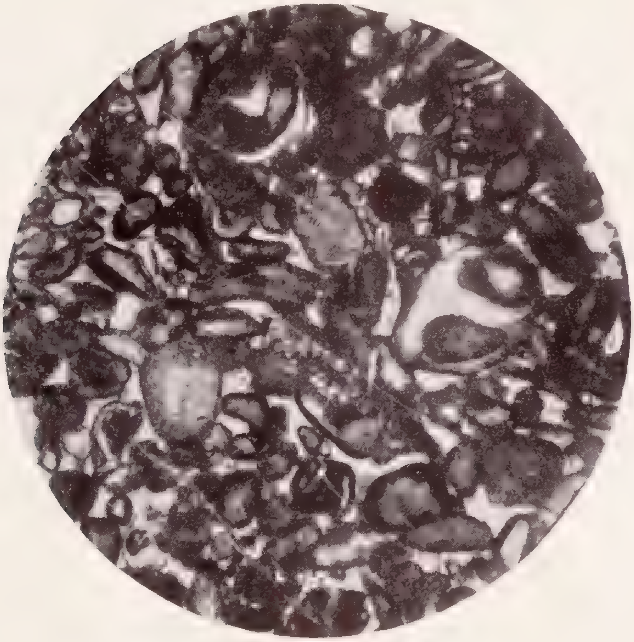
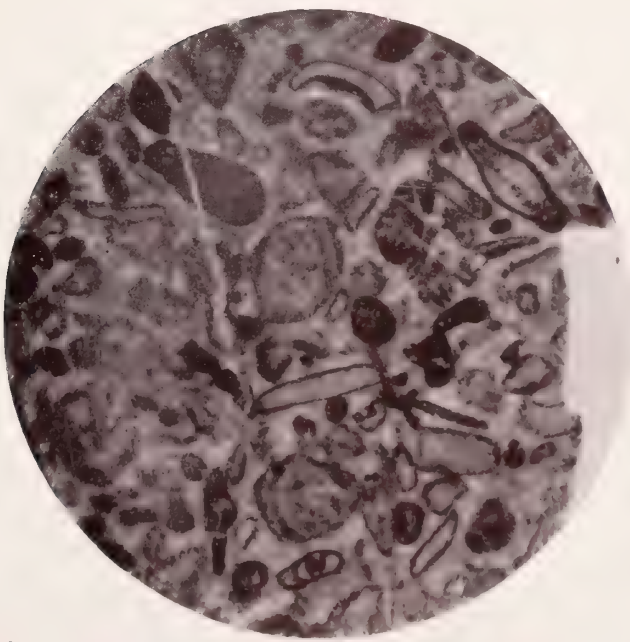


Fig. 1×17. OOLITIC LIMESTONE (? Rhætic), NAM SAWM.



T. H. D. La Touche Photomicro.

Fig. 2×29. OOLITIC LIMESTONE (Rhætic), LOI LAM.

T. H. D. La Touche, Photo.

TERTIARY STRATA AT MAN-SE.

T. H. D. La Touche. Photo.

TRAVERTINE DAMS AT CONFLUX OF NAMYAU AND NAM TU.

T. H. D. La Touche, Photo.

TRAVERTINE DAMS IN THE NAMYAU RIVER, N. SHAN STATES.

T. H. D. La Touche, Photo.

TRAVERTINE DAMS IN THE KE-LAUNG STREAM. WETWIN.

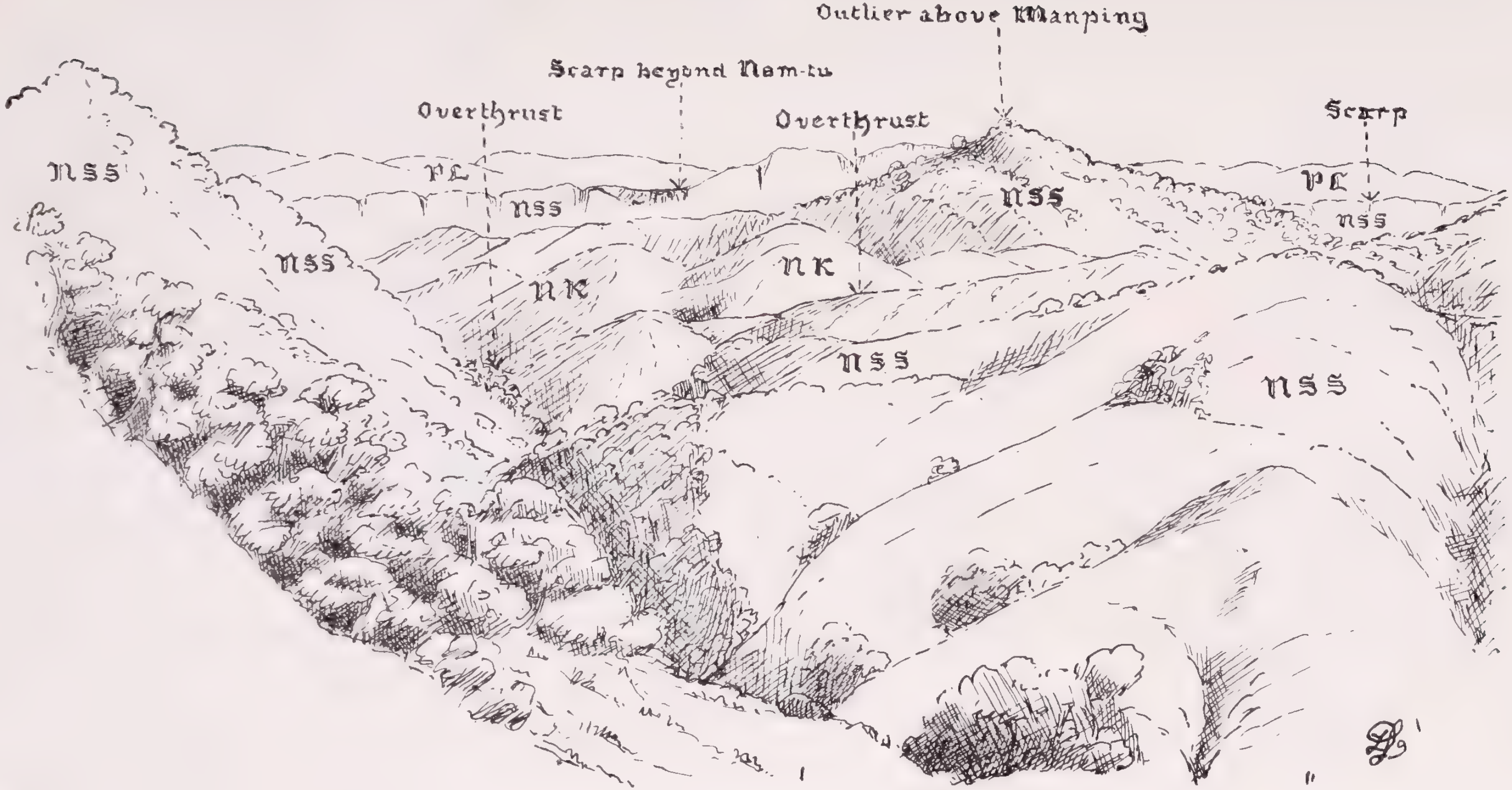
J. H. D. La Touche, Photo.

FISHING WEIR BUILT ON A TRAVERTINE DAM, NAMYAU RIVER.

T. H. D. La Touche, Photo.

RAILWAY CUTTING IN TRAVERTINE NEAR HSON-OI.

Memoirs, Vol. XXXIX, Pl. 22.

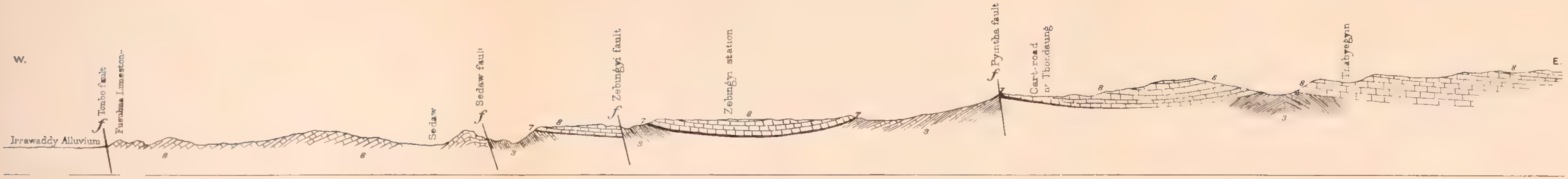


From a sketch by the Author.

View from Monglong (F. I.), looking S. S. E., towards the Nam-Tu, showing position of Lilu Overthrust.

PL. Plateau Limestone. NSS. Namhsim Sandstone.

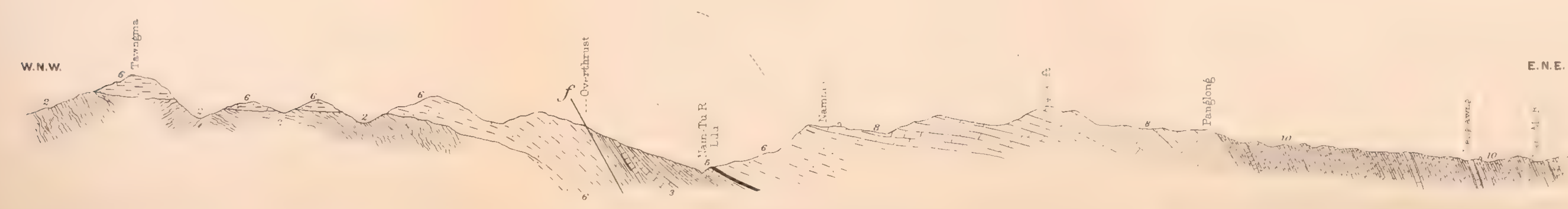
NK. Naungkangyi Shales.



SECTION I. WESTERN SCARP OF PLATEAU. TONBO TO THABYEGYIN.

SECTION II. WESTERN SCARP OF PLATEAU. ALONG MEMAUK SPUR.

SECTION III. WESTERN SCARP OF PLATEAU. CHAUNG-MAGYI VALLEY.

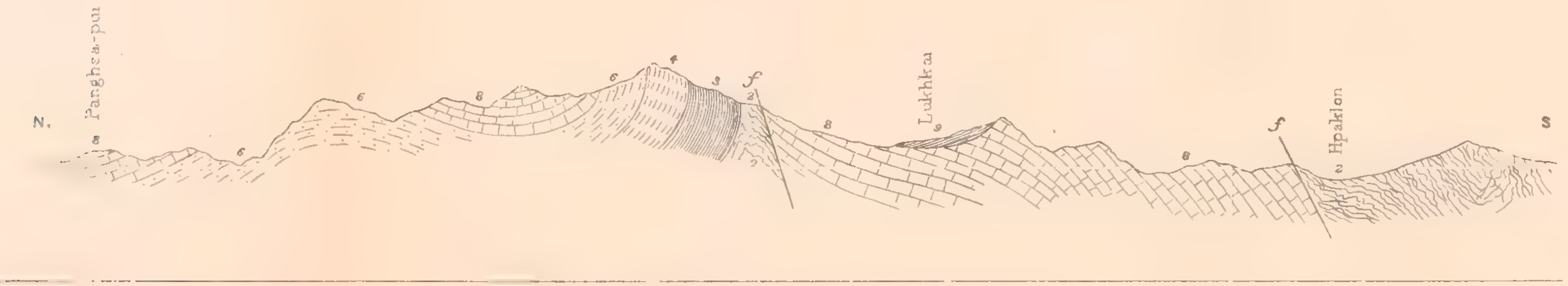


SECTION IV. ACROSS THE NAM-TU VALLEY AT LILU.

Horizontal and Vertical Scale 1 inch = 1 mile.

10. Namyau Beds.
8. Plateau Limestone.
7. Zebingyi Beds.
6. Namhsim Sandstone.
5. Panghsa-Pye Graptolite Band.
3. Naungkangyi Beds.
2. Chaung-Magyi Series.
1. Mogok Gneiss.
f Faults.

SECTION I. ACROSS CENTRE OF LOI-LEN RANGE.



SECTION II. NEAR EASTERN END OF LOI-LEN RANGE.

SECTION III. RANGES EAST OF MÖNG YAI. FROM MAN PONG TO THE NAM HA VALLEY.

Horizontal and Vertical Scale 1 inch = 1 mile.

10. Namyau Beds.
9. Napeng Beds.
8. Plateau Limestone.
6. Namhsim Beds (Upper)
4. Hwe-Mawng Beds.
3. Naungkangyi Beds (Lower)
2. Chaung-Magyi Series

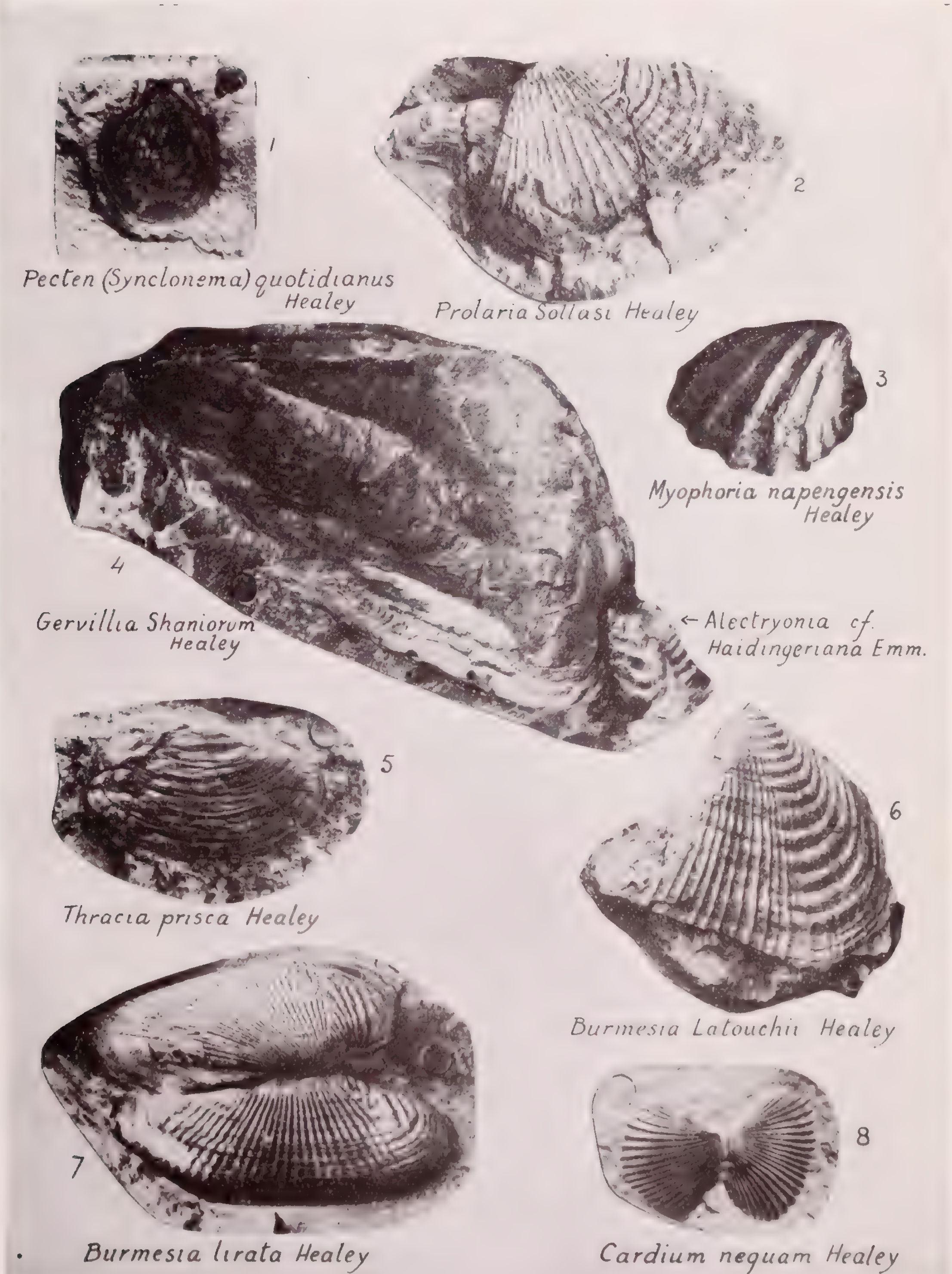
f Faults.

H. E. W. Garrick, Photo.

CAMAROCRINUS ASIATICUS. Reed.
Upper Surface. Natural Size.

H. B. W. Garrick, Photo.

CAMAROCRINUS ASIATICUS. REED.
Lower Surface. Natural Size.



H. B. W. Garrick, Photo.

NAPENG FOSSILS.

All Natural Size.

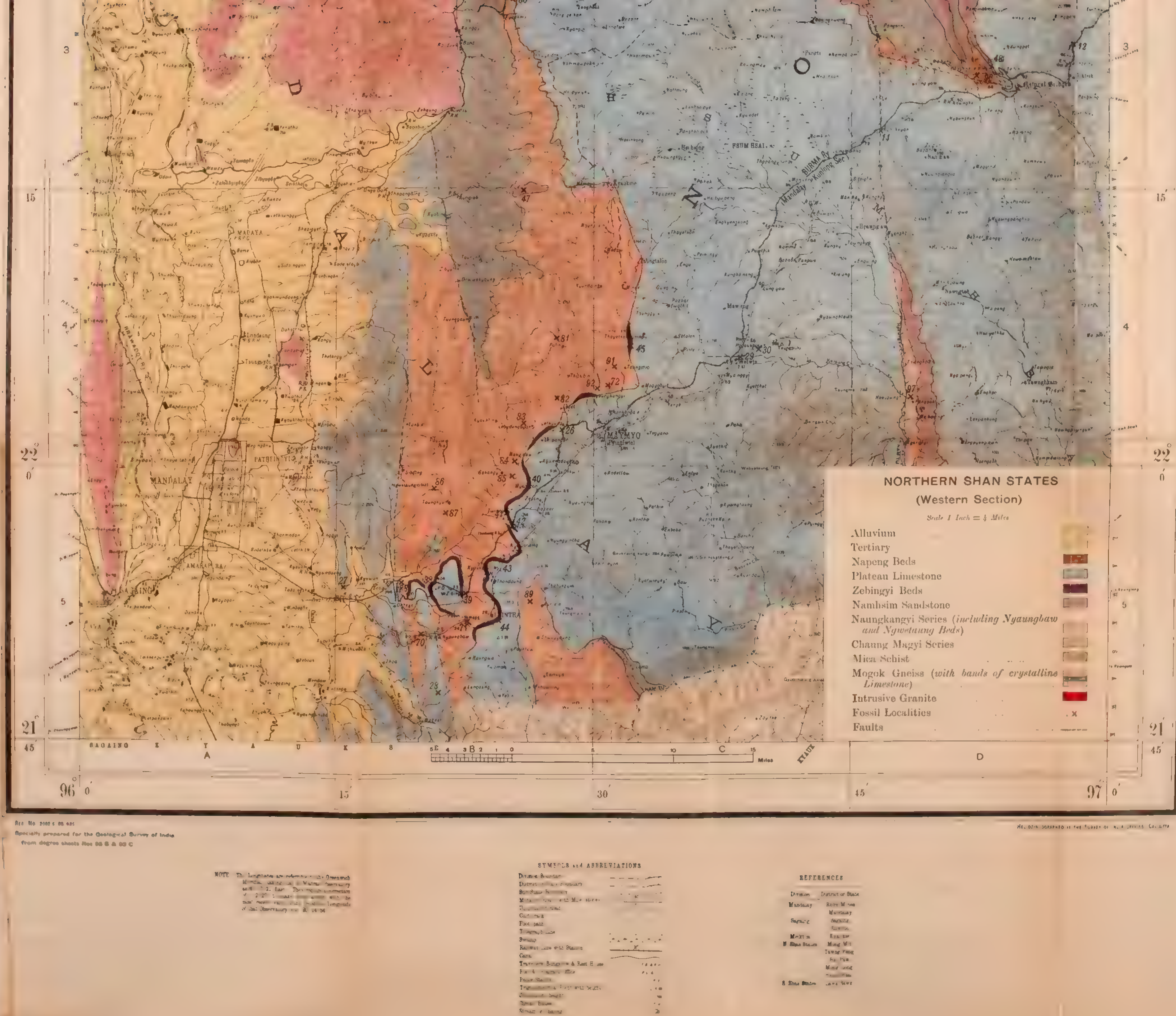

NORTHERN SHAN STATES
(Eastern Section)
Scale 1 Inch = 4 Miles
Alluvium
Tertiary
Namyau Series
Nepeng Beds
Plateau Limestone
Namhsim Series
Hwe-Mawng Beds
Naungkangyi Beds
Chaung Magyi Series
Fossil Localities ×
Faults
MONG YAI

PARTS of BURMA and the NORTH and SOUTH SHAN STATES.

Magnetic Variation 1°45' East.

BURMA

Scale 1 Inch to 4 Miles, or 1.253,440


NORTHERN SHAN STATES
(Western Section)
Alluvium
Tertiary
Napeng Beds
Plateau Limestone
Zebingyi Beds
Namhsim Sandstone
Naungkangyi Series (*including Nyaungbaw and Ngwetaung Beds*)
Chaung Magyi Series
Mica Schist
Mogok Gneiss (*with bands of crystalline Limestone*)
Intrusive Granite
Fossil Localities
Faults
MANDALAY
MAYMYO
BURMA Ry (Mandalay Kunlong Sec)
SAGAING
D
Miles
Specially prepared for the Geological Survey of India
SYMBOLS and ABBREVIATIONS
REFERENCES

PARTS of the NORTHERN and SOUTHERN SHAN STATES. Magnetic Variation 1° 40′ East. BURMA Scale 1 Inch to 4 Miles. or 1:253,440 DEGREE SHEETS Nos. 93 F. & 93 G.

Compiled in the Burma Surveys Drawing Office from Standard Sheets on the Scale of 1 Inch = 1 Mile.

Geological Colouring by T. H. D. LaTouche, Geological Survey of India

Heliozincographed at the Survey of India Offices, Calcutta.

NOTE.—The Longitudes are referrible to the Greenwich Meridian, taking that of Madras Observatory as 80°-17'-21" East. They require a correction of —2'-27" to make them accord with the most recent value of the Geodetic Longitude of that Observatory, viz., 80°-14'-54".

SYMBOLS and ABBREVIATIONS.

Division Boundary
District or State Boundary
Metalled Road (with Mile-stone)
Trade route
Telegraph Line
Railway Line, with Station
Travellers Bungalow
Trigonometrical Point with height
Clinometric height

MEMOIRS

OF

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VOLUME XXXIX, PART 1.

THE GEOLOGY OF NORTHERN AFGHANISTAN: BY H. H. HAYDEN, *Director, Geological Survey of India.*

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Part 2 (out of print).—Geology of Travancore State. Warkilli beds and reported associated deposits at Quilon, in Travancore. Siwalik and Narbada fossils. Coal-bearing rocks of Upper Rer and Mand rivers in Western Chutia Nagpur. Pench river coal-field in Chhindwara district, Central Provinces. Borings for coal at Engsein, British Burma. Sapphires in North-Western Himalaya. Eruption of mud volcanoes in Cheduba.

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